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THE DECEMBER SCIENTIFIC MONTHLY

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THE SCIENTIFIC MONTHLY

DECEMBER, 1929

THE METHOD OF EVOLUTION

By Professor H. J. MULLER

UNIVERSITY OF TEXAS

I. The "Fact" of Evolution

Doubtless most of my readers know the story—it is said to be largely fictitious—of Kaspar Hauser. According to this story there appeared one day on the streets of a town in Germany, about a century ago, a youth, half blinded by the light of day, bent and decrepit, practically unclothed, unable to talk, dazed and befuddled by the objects about him and the persons who crowded round. His origin was traced—so the story goes—to the cellar of a house, then abandoned by its owners, where for some unknown reason he had been kept since infancy, without companions, practically without care, his food being thrust in to him and no knowledge or hint of the outer world being allowed to reach him for some sixteen years. When the owners left he escaped, and was dumbfounded to discover the world. But he was not feeble-minded; he learned to talk; he learned the use of objects and the ways of people, and so, undertaking work and forming human associations, he became drawn into what for most men would be the ordinary stresses and cares of life. The tremendous change seems, however, to have overstrained the powers of adjustment of his cramped mind and body, and he lived a short, tragic life, capped by violent death.

This is a fitting allegory for describing the present situation of mankind—at least, the first portion of the story seems *à propos,* although we may hope that the ending will not be. Mankind to-day is in the position of Kaspar Hauser on his first emergence. For ages we have remained cooped up within blank walls of artificial construction, knowing of nothing beyond, behind, beneath, above; imagining at most another cell or two much like our own cell on the other side of the wall. Unexpectedly, however, through a combination of luck and a certain amount of scheming, we have managed to creep through a series of crevasses in the structure, and have gained a view for the first time of the brilliant real world outside. It stretches far beyond our reach, but is ours to roam.

The vastness of the amount of space and material is but one aspect of this sudden expansion of our universe. The seemingly magical extension of matter inwards, discovering microcosmic realm within realm in the interior of all parts of all things, is another direction in which as yet unlimited vistas have opened. But in following our chosen topic we are concerned more with a third kind of removal of bounds, lying in the realization of the tremendous reaches of time behind and before us, as compared with our primitive conceptions of earth and life history, and in the realization of the immensities of change that have occurred, are occurring and will occur in that life, during periods of time such as we have evidence for. It is this which shakes our human composure, perhaps more than any other revelation

of nature. We were not we; they were not they; things are not as they were and will not be as they are. In the bodies and spirits of living things, as well as in their outer environment, transfiguration has gradually followed transfiguration so as to remake them again and again into totally unrecognizable beings. And more than ever are we now in the grip of these transfigurations.

The protracted reaches of time, with their long-drawn-out processes of transformation, now stare us plainly in the face. Go up the steps of the main building of our university and look beneath your feet: the dead relics of fantastic creatures of the sea that crawled here many millions of years ago are obvious everywhere, ground off to serve as your footrests. Follow with the geologist and trace these changes and others grade by grade. Then delve into the history of your own body, as it unfolded its heritage from the egg, and note the dim rehearsal of past events that it seems so unnecessarily to go through, as by some ritual incantation recounted every generation anew: in your early stages *your* gill slits, *your* fish's heart, fish's brain and fish's circulation, then later *your* split lip, *your* pointed ear, *your* coat of body hair, *your* tail. And note the traces of these obsolete structures, in lowlier creatures so useful, even in your adult selves. Now accompany the breeder of plants and animals to his farm, and let him show his new and fancy varieties. Compare them also with the records of their ancestors and, if you can, deny the plasticity of protoplasm.

Is evolution "a fact"? Am I a fact? What is a fact? The philosopher says that he can not say I am a fact, but that he knows *he* is a fact, and that that is all he knows for sure, but I am not sure he knows that much. However, I will not dispute it with him. He and I and evolution may all be a hoax, but I think we have enough evidence to convince us that we will all have to stand or fall as hoaxes together. And that is enough to satisfy me, at the present stage of the game. If I am a hoax, you may be sure then there is no evolution, and if evolution is a hoax you may be sure there is no me, but if either evolution or I exist, then you need not doubt that the other exists too, and by the same token: for it is by the same process of piecing together, interpolating, a kind of continuity in the intervals between the separated but consistent momentary glimpses of us which you get sense evidence of from time to time, that you can reconstruct a convincing concept of each of us, evolution and me. Certainly, if any one could prove that evolution had not occurred, in spite of the overwhelming evidence we have of it, I should have my conception of the consistency of the universe so destroyed that I should see little reason left to credit the truth of my own existence. So remember, if you will, evolution is not a fact—no, not at all—no more a fact than that I exist or that you are reading the words on this page.

It ill befits us, however, to remain wrangling over such abstractions when we stand confronted with the view of a great hitherto unknown world of which we form a part. Admitting, for purposes of living, the reality of this world of ours, we must forthwith bestir ourselves to find out its possibilities and the rules which govern its activities. Even though we may be but as little motes drifting helplessly in its great currents, still we can not keep our self-respect as men without striving to understand its operations, and, if possible, to make at least some little impression upon them. What, then, are the methods of operation of these great evolutionary processes in which all life has been caught?

II. The Quarrel Over the Causative Agent

It is here that the real doubt and divergence of opinion among the so-

called "experts" has been supposed to exist. "Darwinism is dead," it is sometimes parroted, and though Kammerer died tragically by his own hand, the hypothesis of the inheritance of acquired characters which he among others advocated is claimed to have plausibility. Many, if not most, medical men still believe in it, but some philosophers prefer evolution through a kind of inner drive—"orthogenesis"; still others who make themselves heard believe that instead, or in addition, there is a direct influence of the kind of environment upon the kind of variations that occur, with the result that fitter and fitter, or occasionally, less and less fit, organisms are brought into being. To "explain" the fortunate adaptive responsiveness on the part of the organism, the guesses range from an internal, rather short-sighted, cell-intelligence, the "entelleche," to an external, far-visioned perfecting principle.

Amongst the various voices—so our students have to learn from some contemporary texts—there are also to be heard the voices of "neo-Darwinians," who arrive at a finite end by an almost infinite number of steps, or slides, back and forth, of almost zero individual magnitude, the backslides, however, being each time discontinued. And opposed to these, it is often stated, are the voices of different kinds of "mutationists." Some of the latter would have one adapted species change directly into a differently adapted species by just doing so; others would have each more advanced type emerge out of the more primitive type by losing an inhibition. Then, too, there are the voices of those claimants who say that new products arise only by the crossing of preexisting types, followed by the formation of a combination type representing certain elements from each of the old. It is not explained here whether the second species arose by crossing between the first and third or whether the third species arose by crossing between the first and second, or both. Altogether, you see, this is not a process of a species raising itself by its bootstraps—not so crude. Here *A* lifts *B's* bootstraps, and *B* lifts *A's*, onward and upward forever!

After such a maze of opinions, of which these form only a part, the slate is left pretty blank (or rather, evenly scrawled over) for the teacher, the student or the outsider to write in, large, his own personal beliefs. Among these, there is one belief which is especially common. It starts out by stating that every effect has its cause, and a definite effect has a definite cause, and goes on to say that therefore it is only reasonable to suppose that a definite kind of variation, or difference arising between an offspring and its parent, must have been due to some definite condition or quality of stimulus, within or surrounding that parent, whether we can at present trace it or not. A repetition of this condition then would bring forth a similar variation again. In some quarters it is added further that such causation must therefore tend in itself to explain the course of evolution. This in turn would seem to circumvent the necessity of invoking "natural selection" to do more than help out in a secondary and occasional fashion. For, it is often said, it feels "*philosophically unsatisfying*" to believe that all the order and organization of living things could have come about through such a chance process as natural selection admittedly is.

It is evident that a real decision of the questions at issue can be reached only on the basis of real data regarding the nature of those differences which distinguish one generation of individuals from its predecessors, and which they in turn tend to transmit as a heritage to their descendants. That is, we must not remain content to view evolution from afar, but must view close up, as through a microscope, the transitions now occur-

ring out of which the evolutionary story is pieced together. The science which essays this study is "genetics."

III. Genetic Principles Reviewed for the Non-biologist

During the present century genetics, building upon the earlier discoveries of Mendel, has practically solved the problem of the method of inheritance of the differences referred to, once they have arisen. All modern genetic work converges to show that the heritable differences between parent and offspring, between brother and sister, in fact, between any organisms which can be crossed, have their basis in differences in minute self-reproducing bodies called the genes, located in the nucleus of every cell. The genes themselves are too small to be separately visible, but hundreds or thousands of them are linked together into strings, and these strings of genes, together probably with some accessory material, are large enough to be seen through the microscope by the cytologist; they constitute the sausage-shaped bodies called chromosomes. We know that, ordinarily, each individual gene in a string is different from every other gene in the same string, and has its own distinctive rôle to play in the incomparably complicated economy of the cell. Moreover, the genes in different chromosomes are different from one another, except in the case of homologous or twin chromosomes, *i.e.*, the corresponding chromosomes which each cell of an individual received from the father and from the mother of the individual, respectively. To match each chromosome that was derived from your father, every cell of you has in it also a similar chromosome (though not necessarily quite identical) derived from your mother, so that it contains in all two complete sets of chromosomes and hence two complete sets of genes. The proper functioning of the cell during its life depends upon the proper cooperative functioning of its thousands of different genes. One complete set of genes would ordinarily be enough for this, but two sets are provided, so that new combinations of the characteristics of different ancestors may be tried out.

Each given gene in the cell must of course have its own specific chemical composition, differing from gene to gene, though there is no doubt a chemical relationship between all genes. As yet, however, we have no knowledge as to what the chemical composition of any individual gene, or of genes as a group, is. Whatever it is, we can not escape the fact that the different genes, through differing chemical reactions with other substances in the cell, produce by-products which have a very profound influence upon the properties of the protoplasm. And through the combined influences of all the chemical products of the thousands of different genes in a cell, meeting one another in the common protoplasm and then interacting in devious ways to form further products again, the exact form and physical and chemical characteristics of all parts of the cell that contains those genes will be determined, for any given set of outer conditions. Changing conditions external to the cell will of course change the properties of the protoplasm too, but what form and behavior it can and will show for a given set of outer conditions depends primarily upon what genes it has. And since the body of a man or other animal, or a plant, is made up of its cells, and the form and other properties of that body depend upon the properties of these constituent cells—their form, the way they fit together and work—it is evident that, less directly but no less surely than in the case of the individual cells, the characteristics of the whole body depend upon the nature of the genes in the individual cells.

These individual cells of the body have, during the development of the

embryo, been derived from the original fertilized egg cell, through a succession of cell divisions in the course of each of which every chromosome and every gene present in the dividing cell also divided in half, one half of every chromosome and gene then entering one of the two daughter cells and the other half entering the other daughter cell. Between divisions the chromosomes and genes usually had a chance to grow back to their original size. Thus it results that every cell of the body has the same kinds and numbers of chromosomes and genes as the fertilized egg had, and as every other cell in the body has. The original two sets of genes of the fertilized egg—one set received from the sperm of the father, the other similar set derived from what the egg of the mother contained before fertilization—are still both present in every cell of you. But these two sets of genes of the fertilized egg were all, and more, than were needed to result in a complete man. We see, then, that every single cell of you, in the skin, the brain or anywhere else, contains the makings of a complete man or woman, and that you are in this sense wrapped up within yourself many trillion fold. Not each cell may grow up into an entire man, of course, but must remain content to do its specialized share, even though it has a full cargo of genes, because its structure and activities are limited and regulated in various ways through the mutual influences received from the other cells in the body. The various cells of different organs developed differently from one another because, though possessing the same genes, they found themselves in different situations, subject to different influences, from the start. Only the germ-cells, then, may eventually realize anything like their full potentialities.

All this explanation, somewhat off the main theme, may serve to furnish some sort of notion of how the characteristics, in fact the entire substance, of any human or other living being depend upon its genes, acting in a chemically coordinated fashion. So complicated is the manner in which the products of the different genes react with one another that no final product and no characteristic of the adult body is due to any one specific gene, but in the production of every organ, tissue or characteristic, numerous genes take part. Nevertheless, if one individual differs from another individual in regard to just one of the genes that do take part, it will be seen that the given characteristic in the two individuals will be different, and so, conversely, a difference between two individuals in regard to a certain characteristic, let us say eye color, may be due to a difference between just two given genes in them rather than other genes. We may then call these for short the genes "for brown" and "for blue" eyes, respectively, while remembering that really, in both individuals, many other genes are present also which are helping to produce the exact eye colorations seen, but that these other genes happen to be alike in the two individuals in question and therefore are not causing this particular difference, between this brown eye and this blue eye.

By studying the characteristics that appear among the descendants in later generations, after individuals differing in regard to one or more genes have crossed together, the definite Mendelian laws and the laws of linkage governing the inheritance of genes have been determined, and they are found to have a practically universal validity. There is no use attempting here to formulate in detail these rules and their working out; this usually occupies the major portion of a course in genetics. It is sufficient to call attention to a few pertinent facts.

When two germ-cells that differ in respect to a certain gene, *e.g.*, the egg having the gene for brown and the sperm

that for blue eyes, fertilize each other, neither gene is lost, but the resulting individual possesses both genes in every one of his cells, even though his eyes may show preponderantly the brown color, brown being said to be the dominant gene and blue the recessive. Half the germ-cells formed by an individual of such mixed composition ("heterozygous," we call him) will carry the brown gene and not the blue one, the rest carry the blue gene and not the brown, and so there is as good a chance for any one of his children to inherit the blue gene as the brown one. Moreover, it is found that neither the blue gene nor the brown one, when inherited by the next generation, shows any weakening or other trace of its former sojourn with a gene of opposite character. It persists through the generations uncontaminated by its associate-genes.

Now if the individual of dual composition had also been dual (heterozygous) in regard to some other kind of gene, say for hair shape, having received the gene for curly hair from the parent that gave him brown eyes, and the gene for straight hair from the parent that donated to him the gene for blue eyes, then, although he would probably show moderately curly hair, nevertheless, as in the case of the eye colors, half of the germ-cells which he produced would carry curly and the rest would carry straight. However—and here lies the important point—not all those germ-cells of his that carried brown would be the ones carrying curly, nor would all those carrying blue carry straight; there would be some carrying the combination, new perhaps for this family, of brown eyes with straight hair, and other germ-cells carrying the converse new combination—blue eyes with brown hair. Thus, by crossing and recrossing individuals with different genes, new combinations of these genes will be produced in subsequent generations until all possible combinations of the differing genes in crossable individuals have been given a trial. Occasionally totally new effects, new characteristics, are thereby produced, when some new combination is obtained through the unexpected interaction of genes which never before had been tried out together, but such cases are rare. Were the process just described the only method of obtaining change in the characteristics, or combinations of characteristics, of organisms, evolution would soon reach its limit.

On analyzing the results of various crosses, it is found, as might have been expected, that closely related individuals differ in respect to relatively few (though sometimes absolutely many) genes, so-called unrelated individuals of the same race differ in more genes (in fact, in about twice as many as do brothers or sisters), individuals of different races differ in still more genes, and those of different species, where the crosses can be made and analyzed, are found to differ in a yet greater number. In each case, however, the differences are of the same general nature—differences in ordinary genes in the chromosomes, that normally are handed down in heredity in the orthodox Mendelian fashion. In fact, in some cases, as Baur and others have found, the difference between two members of a family may be in regard to the very genes which also distinguish two different species as a whole. The species-differences, then, are simply more abundant, and have had a chance to become more select(ed). And there is every reason to believe that the same is true of the differences between more widely separated groups (with the further proviso, that the number and arrangement of the genes, as well as their kind, may be different). For, in the course of evolution, as one species changed into another and then again into another, it would gradually diverge so far from its progenitors as to be placeable in a separate genus, then in a separate family, order, class, etc., al-

though all along differences would be accruing in the same manner as before. If they can accrue in any other manner we should by this time have gotten evidence of it. But we are running ahead of our story, for the manner of origin of the differences has not yet been considered here.

Most of modern genetics has been occupied with tracing down the above "facts" (if this term may now be used, subject to the qualifications previously expressed). They relate essentially to the method of transmission, to later generations, of gene-differences that are already found to exist between individuals. They show the universality of these differences, their comparative permanence and their recombining capabilities. But they leave untouched what now becomes the major question—how do such differences originate in the first place? What is the origin of variations?

A hitherto rather incidental, yet very important, part of modern genetics has had to do with the problem just raised. It has been discovered definitely that differences between genes do arise, *de novo*, as it were. That is, not all the gene-differences now existing in a population have existed in it from the beginning. New differences are continually arising, somehow, and the differences now existing have undoubtedly arisen in the past in a manner similar to these.

Each gene-difference arises suddenly and full-fledged, though we may not be aware of it at once. Thus, in a population of gray-colored mice, suddenly, in a certain cell of one individual, one of the genes whose cooperation is necessary for the production of the gray color undergoes a change into a gene of different composition that tends, in its interaction with the other (unchanged) genes for color, to produce a yellow tinge instead of a gray. In this single cell, however, the change will not be observed by us. But if this cell, or one of the cells derived from it, happens to be a germ-cell, an offspring-individual may be formed in the next generation all of whose cells carry this new gene. Then if the new gene is dominant (as it happens to be in the case of yellow *versus* gray in mice) to the old gene for gray which the offspring has received from its other parent, the coat of the new animal will be yellow, and we will see that a mutation has occurred. But if the new gene had been recessive, the gray dominant, the offspring would have appeared gray like its parents and we should not yet have been aware of the mutation. The new gene might persist none-the-less, and be inherited by generation after generation in invisible fashion, being meanwhile "dominated over" by the gray from the other parent. If in a later generation two descendants both of which carried the mutated gene happened to mate together, an egg with the yellow might become fertilized by a sperm also carrying yellow, neither, therefore, carrying the dominant gray, and from such a union a visibly yellow offspring would emerge for the first time. A mutation, when recessive, may accordingly fail to manifest itself for many generations, or may never have a chance to show itself at all, before the line of individuals carrying it becomes extinguished. (It has been shown by Fisher that most mutations must meet this mute inglorious fate.)

The new gene, once it has arisen, is ordinarily as stable as the old. The change is definite and fixed, evidently of a chemical nature. Once it has occurred, we have a new mutant gene which will eventually either spread throughout the population or be killed off, according to whether the individuals which carry it reproduce more offspring or fewer.

The effects of mutations are of course as varied as the gene-differences which are found to occur within populations, since these gene-differences originated by

mutation. Some gene-differences, some mutations, produce large and startling effects, like growing a leg on a fly's forehead. Some affect the whole body in practically all its parts, others change two or three characters, others apparently but one. But the less conspicuous changes, the insignificant effects that are easily overlooked, or that even, in many individuals, quite overlap the normal type, seem at least as apt to occur as do the pyrotechnical varieties. Evidence is not lacking that physiological changes, and changes that can only be detected physicochemically, are probably as frequent as changes in visible structures, but geneticists have till now had to have a predominantly morphological training, and anyhow the morphological is easier to see and deal with. It would be absurd and scholastic to try to classify mutations according to the nature of their effects. A mutation can do practically anything that life can do—or at least a little of it, for life is built out of mutations.

IV. The Randomness of Mutations

The statement just made does not necessarily mean, however, that the average mutation does very much in the furthering of life. You will recall that perhaps the biggest question among the older schools of evolutionists was this: Do variations have a tendency to be adaptive, to further life? Is there any evidence in them of an internal or external adapting or perfecting principle, call it what you will? Any kind of inheritance of acquired characters, orthogenesis, direct adaptation of the germ-plasm to environment, or single-stepping origination of species requires this. What do the data on the actual occurrence of mutations show?

They show just the opposite, and in so doing they support Darwin. The vast majority of observed mutations are positively detrimental, and handicap the individual less or more in the struggle for the survival and reproduction. In fact, as Altenburg and I showed in some studies on the fruit-fly, *Drosophila*, in 1919, by far the greater number of detectable mutations in it are actually lethal: their effect is to kill the animal before it becomes adult (though of course their effect may be prevented if they are recessive and if the dominant normal gene has been received by the individual from its other parent). Evidence is accumulating that the same situation probably holds in other forms of life. Now this is just what we should expect, and did expect, on the basis of the theory that a mutation is a chemical change in a gene, occurring at random, as it were—that is, without reference to the effect that would be produced, a-teleologically. Suppose you prod the innards of a watch at random—bring about some alteration in ignorance of the effect it may have. Are you likely to make it a better-running watch? A change, purely accidental in this sense, wrought in any complicated organization is more likely to injure or wreck than to improve that organization for the specific function (in the case of life, multiplication) which it subserves. But, unless the organization has reached its absolute maximum of efficiency already, there will still remain *some* changes, and therefore *some random* changes, that will help. And so, occasionally, when your watch has stopped or is running poorly, you may knock it, prod it, or drop it, and find that, by the lucky replacement of a cog, or the displacement of a sand grain, it starts up merrily again. We shall return to this topic later. Meanwhile, we stand on our data: despite the staggering complexity of adaptation in living things, the vast majority of mutations are, as is to be expected, anti-adaptive.

It will not suffice, however, simply to call the changes "accidental." An acci-

dent is something whose cause was independent of something else you are interested in, but every accident has its cause just the same. And so we return again to our perennial question: What is the cause of mutations? Evidently, we may now say, not any outer or inner tendency toward perfection of the life force, but that does not help us very much, scientifically. The mutations whose origination has been known to geneticists have been on the whole very scattered and sporadic, so that little of definite information could be obtained, by collecting these observations, concerning the conditions which may have been contributory to their occurrence. The trouble was that mutations having a conspicuous visible effect are so very rare anyway that one does not find enough in any one experiment to "count." However, the very negativeness of this result, and the varied character of the mutations as they did occur, suggested that their occurrence had little or no relation to the ordinary variables of the environment.

Altenburg and I, in the work previously alluded to, undertook a more systematic test of the possible effectiveness of temperature, by using a technique by which we could count the occurrence of lethal mutations, since we found these arose so much oftener as to be countable, and we obtained results indicating, though not proving, that a rise in temperature caused a slight increase in mutation frequency, even as it hastens chemical reactions. Later evidence seems to substantiate this, but the result at best scarcely goes far enough to afford a workable handle for the study of mutation phenomena, since the numbers obtained even here are so trifling in response to the great expenditure of technical effort necessary. In addition to this work, efforts have been by no means lacking, on the part of numerous investigators, to find the cause, or a cause, of visible mutations, by trying all sorts of maltreatments in the attempt to produce such changes. In the course of this work, animals and plants have been drugged, poisoned, intoxicated, etherized, illuminated, kept in darkness, half-smothered, painted inside and out, whirled round and round, shaken violently, vaccinated, mutilated, educated and treated with everything except affection, from generation to generation. But their genes seemed to remain oblivious, and they could not be distracted into making an obvious mistake in the reproduction of daughter genes just like themselves. The new genes were exact duplicates of the old ones, showing no demonstrable mutations, or at most such a scattering few as might have occurred anyhow.

Either the technique used for finding the mutations was inadequate, or the treatments had little or no effect upon the composition of the genes, or both, and I am inclined to think the latter is correct. And yet mutations certainly do happen, even though rarely. In the examination of over twenty million fruit-flies, not specially maltreated, over four hundred visible mutations have been found. These mutations must have causes. What then can the causes be? What subtle conditions are they, apparently so independent even of violent injury and of other drastic and obvious changes in the physiological or pathological state of the organism? In going over the data on mutational occurrences in *Drosophila* the present writer in 1920 reported the finding of evidence that in this fly, when a mutation occurred in a given gene of a cell, not only did the hundreds or thousands of genes of other kinds in that cell remain unchanged, but even the twin gene of the other set in the same cell—*i.e.*, the originally identical gene that the individual had received from its other parent—remained unchanged also. Here, then, are two genes of identical chemical composition, lying

very close to one another in the same cell —on the average less than a thousandth of a millimeter apart—and one of them is caused to mutate but its duplicate is not. Neither do the identical genes in neighboring cells mutate. Evidence for this same kind of occurrence has been adduced in other organisms. Why do not the same general conditions, acting on the same materials, produce everywhere the same results? If events in this sphere are apparently so indeterministic, is it any wonder that we could not in our previous trials, by the application of definite conditions, produce definite mutational results?

In view of these accumulating findings, the conclusion seemed to me to become increasingly probable, not that mutations were causeless, or expressions of "the natural cussedness of things," or of the devil, but that, as Troland had suggested prior to the finding of this evidence, they were not ordinarily due directly to gross or molar causes, but must be regarded as the results of individual ultramicroscopic accidents—events too far removed from us in fineness to be readily susceptible to any exact control on our part. In other words, an appeal was made to the newly found world of the little to which I alluded in the beginning, and which the old-line biologist and philosopher do not always take sufficiently into consideration.

The genes are not only protected by a cell membrane but by a nuclear membrane inside of that, and possibly again by a chromosomal envelope of some kind; they may be well shielded, therefore, from the reach of any poisonous substances or unusual products of metabolism. They can not, however, escape the interplay of the helter-skelter molecular, atomic and electronic motions that are continually taking place both within and around them, on the part of the substances of which they and their neighbor molecules are naturally composed. Nor can they escape the buffeting action of the electromagnetic stresses and strains occurring through space in the field in which they lie immersed. These various exchanges of energy are not, it is evident, ordinarily consequential enough, or the energy is not directed in sufficiently telling ways, to so distort a gene as to change its composition permanently. Occasionally, however, such a change does occur, and subsequent generations tell the tale.

V. X-Rays a Cause of Mutations

If this general conception of mutation is valid we must regard it as being merely a kind of placing of the problem; we should not yet know just which were ordinarily the critical processes concerned, still less the exact steps involved. The conception carries with it, however, suggestions for further experimental investigation. For among the agents of an ultramicroscopically random character, that can strike willy nilly through living things causing drastic atomic changes here and passing everything by unaltered there—not a ten thousandth of a millimeter away, there stand preeminently the X- or γ-ray and its accomplice, the speeding electron. There is nothing in protoplasm which can effectually stop the passage of X-rays or the related waves of shorter wave-length—gamma and cosmic rays. For the most part, in a cell, the rays will pass through; but at isolated, unpredictable spots, depending upon unknown "chance" details of energy-configurations, a definite portion, a "quantum," of the rays will be held up, and part of the energy thus absorbed will issue forth in a hurtling electron, shot out of the atom that stood in the way of the radiation. The atom will be changed thereby, and hence the molecule in which it lies may undergo a change in its chemical composition. But for every atom thus directly

changed there are thousands of other atoms changed indirectly. For the electron, shot out like a bullet (except far faster), tears its path through thousands of atoms that happen to lie in its way, leaving in its wake a trail of havoc before it is finally stopped. In this process, many of the atoms through which the electron tears have one or more of their own electrons torn out or dislodged from their proper places; this change in the structure of the atoms often causes them to undergo new chemical unions or disunions that in turn alter the composition of the molecules in which the atoms lay. If a gene is a molecule, then, with properties depending upon its chemical composition, it can be shot and altered by the electrons resulting from the absorption of X-rays or rays of shorter wave-length. The only question would be, can enough mutations be caused in this way to be detectable by our present methods, with doses of rays small enough not to kill or sterilize the treated organism?

With these points in mind, the author undertook in the fall of 1926 a series of experiments designed to test the question at issue. The fruit-fly, *Drosophila*, was used, since it is so easily and rapidly bred in large numbers and since it rendered possible the employment of special genetic technique for the finding of mutations, that had been elaborated in the course of my previous work on linkage and mutation in this organism.

It would take us too far afield here to examine this technique in detail. Stocks of flies had been made up containing in given combinations certain genes with conspicuous effects which would serve to notify the investigator that the chromosome under consideration was present. On making given crosses of these stocks with other stocks various combinations of characteristics would be expected in the first and following generations. If flies with some particular expected combination were, however, absent from a given culture, it would mean that a mutation had occurred that had given rise to a lethal gene—one that had killed the flies containing it before they had a chance to hatch. By noting which combinations were missing it could be deduced which chromosome of the fly the lethal was in, and at what place in the chromosome it lay. On the other hand, mutant genes having visible instead of lethal effects would be detectable through the appearance of the visible variations, and these too could be traced to their chromosome position through studies of the nature and frequency of the combinations in which they appeared. Mutant genes that were recessive to the normal type, however, and most mutations are recessive, would not have a chance to be seen or found until the second or third generation of offspring, subsequent to their origination. The reason why recessive mutations are not evident at once has been explained previously.

In these experiments the adult flies—in some cases the males, in other cases the females—were placed in gelatin capsules and subjected to doses of X-rays so strong as to produce partial sterility, though the other functions of the flies are not noticeably disturbed by a dose several times stronger than used here. The treated flies were then bred to untreated mates, and at the same time numerous control matings of the same genetic type were carried on for comparison, consisting of untreated males crossed by untreated females. Thousands of cultures were used in this and subsequent experiments, in order, if possible, to settle the matter beyond any doubt.

The results in these experiments were startling and unequivocal. To the toiling pilgrim after plodding through the long and weary deserts of changelessness, here indeed was the Promised Land of Mutations. All types of mutations,

large and small, ugly and beautiful, burst upon the gaze. Flies with bulging eyes or with flat or dented eyes; flies with white, purple, yellow or brown eyes or with flat or dented eyes; flies curly hair, with ruffled hair, with parted hair, with fine and with coarse hair, and bald flies; flies with swollen antennae, or extra antennae, or legs in place of antennae; flies with broad wings, with narrow wings, with upturned wings, with downturned wings, with outstretched wings, with truncated wings, with split wings, with spotted wings, with bloated wings and with virtually no wings at all. Big flies and little ones, dark ones and light ones, active and sluggish ones, fertile and sterile ones, long-lived and short-lived ones. Flies that preferred to stay on the ground, flies that did not care about the light, flies with a mixture of sex characters, flies that were especially sensitive to warm weather. They were a motley throng. What has been done? The roots of life—the genes—had indeed been struck, and had yielded.

It must not be supposed that all the above types appeared congregated together in one family. The vast majority of the offspring that hatched still appeared quite normal, and it was only by raking through our thousands of cultures that all these types were found. But what a difference from the normal frequency of mutation, which is so painfully low! By checking up with the small numbers of mutants found in the numerous untreated or control cultures, which were bred in parallel, it was found that the heaviest treatment had increased the frequency of mutation about 150 times—that is, an increase of 15,000 per cent.

VI. Similarity of the X-Ray to the Natural Mutations

Yet these mutations were obviously of the same general nature as the spontaneous mutations that occur without X-ray treatment. This was shown by the fact that in many cases changes had been produced which were undoubtedly identical with spontaneous variations which had been found in the previous history of the *Drosophila* work; the effects in these cases appeared identical in every particular, and the method of inheritance, the position of the gene concerned in the chromosome, was found to be the same. In fact, in the chromosome which has been subjected to the most intensive study (the X chromosome), the majority of all the well-known mutations that had previously been found by the dozen or so active investigators in the course of fifteen years now were found to have arisen over again in the cultures of X-rayed flies here. Besides these reappearances there were of course many new types also, more new types than old, but it should be remembered in this connection that new types are continually being found, though with far lesser frequency, in the untreated material also.

The new types of mutations, like the old, conformed in their general expression and mode of inheritance to certain general principles which I have previously observed to hold in the case of the mutations occurring in untreated material. One of these principles was that the great majority of the mutations—of X-ray as well as of natural origin—are recessive to the normal type, despite the presence of a rather small minority of dominants. Thus the technique of breeding out through a number of generations in order to find the mutations was found to be justified. And it may be remarked here that if human beings are affected by X-rays in the same way as flies, we can not expect to find much evidence of a mutational effect of X-rays on them from data derived only from the first, or even the first, second and third human generations, and such a negative result will therefore by no means indicate a lack of significant genetic effect.

The second principle observed was that the X-ray mutations, like the natural ones, included both inconspicuous as well as conspicuous changes, changes of slight or almost imperceptible degree as well as striking changes of structure or quality, and changes that registered their effect, so far as could be determined, only in slight lowerings of the general vitality, as well as those that were more graphically describable. If anything, the more easily overlooked effects were the more frequent.

A third principle noted was that most of the X-ray mutations were in some way detrimental to the animal in living its life—they were steps in the wrong direction in the struggle for existence. This finding has already been discussed in the case of the natural mutations, and it has been explained that this is just what is to be expected, on the whole, of changes that occur at random, accidentally, "by chance"—I care not what term you wish to use to describe the idea that they occur without reference to their consequences, unadaptively, and hence are more likely to be "wrong" than "right" changes, just because there are more wrong roads than right roads to follow, and because, as is well known, the right road is apt to be the narrower. In the case of the X-ray mutations it is easily seen that, if the change occurs as I have pictured it, it *must* occur accidentally, without reference to the possible advantage or disadvantage it would confer, since the shooting electrons let loose by the X-rays are coursing helter-skelter through the cell, quite blindly, and are just as apt to hit one gene as another, to strike it either on its left or its right side, through its heart or its appendix, so to speak, and so will cause one change or another indiscriminately. We have in the X-ray mutations, then, a group of variations which seem *necessarily* to be random, and hence would necessarily be mostly detrimental. In view of this, it is interesting to compare with them in this respect the natural mutations, and to note that, so far as our evidence goes, the natural mutations have, on the average, every bit as much tendency to be detrimental as the X-ray mutations have. The obvious conclusion is that the natural mutations too must be random changes, in the same sense that the X-ray mutations are.

As in the studies on natural mutations, so too among our artificial ones, the great majority were lethal—they killed the fly before it ever hatched, except where there was a normal gene from the other parent to dominate over the lethal and save the fly's life, so that it could be bred and the method of transmission of the lethal studied. The changes in wings, eyes, etc., previously mentioned were only the exceptional visible changes, culled from out of a great mass of lethals. Thus, although the great majority of the descendants of X-rayed flies that lived *looked* normal, many of them carried, hidden by the dominant normal gene, a recessive lethal gene. And if we count up all these lethals we find that the majority of the offspring of heavily X-rayed flies are not really normal in their genes after all, for something over 50 per cent. of them contain some kind of lethal mutation that will not work its destruction until a still later generation. This too deserves being considered in its bearing on X-ray effects in the case of human beings. Now previous studies of Altenburg and myself on natural mutations have shown that among them too, although the total frequency of mutations is so much smaller, nevertheless the number of lethals is just as large, *relatively* to the number of other, visible mutations which occur naturally, as it is among the X-ray mutations. As the lethals differ from the others, after all, merely in being more detrimental, this result simply means again that natural mutations

are just as apt to be very detrimental, *i.e.*, lethal, as are X-ray mutations, thus confirming what I have called the "accidental" character of the natural mutations.

The descendants of the X-rayed flies have been bred through many subsequent generations. It has been found that, where a gene was not caused to mutate in the first place, it will not show a subsequent tendency to mutate, without further treatment, *i.e.*, there is no perceptible after-effect on the genes that escaped an immediate hit. On the other hand, those genes that were hit and mutated now breed true to their new type, which in the great majority of cases gives evidence of being as stable as the original type was before treatment. We now have in the laboratory various mutant races of flies, derived from our earlier X-ray experiments, which have passed through something like fifty or more generations since the time the mutation took place, and there has been no sign in them of any tendency to revert back to the originally normal condition. They have their own, new norm; they are real, new variants. The new forms are permanent, in so far as the word permanent may be applied legitimately to living things. And when crossed to other forms, the new differences obey the same laws of Mendelian and chromosomal inheritance as do the gene-differences existing between natural varieties.

VII. The Nature and Significance of the Genetic Effect of Radiation

It might perhaps be contended in some quarters that while the artificial mutations may be similar in some respects to natural ones, and even identical with some natural ones, yet they may not be similar to those particular natural mutations which may be termed "progressive": the mutant genes resulting from which survive, multiply and thus become a part of the heritage of an evolving species. Such claimants would hold that the X-ray action is necessarily destructive, causing only loss and injury, and that thus it can work *only* harm, or at least can cause no indefinite amount of progress in organization. Such a contention would rest upon a misconception of the action of the X-ray, for it can be shown that the speeding electron is capable of imparting energy to other atoms through which it goes, and that the resulting chemical changes may be of a synthetic character as well as otherwise. However, since we can not analyze chemically the real nature of the changes involved in the production of mutations by X-rays, empirical evidence on the question at issue is called for, and that is what we have been trying to obtain.

It is evident, as my wife has suggested, that if the change induced by X-ray from, say, a gene designated as large A, to a mutant gene of different composition, designated as small a, has really involved a destructive process or a loss, then the opposite change, from small a to large A, must, conversely, involve a constructive process or a gain. With this question in mind, Professor J. T. Patterson and I have been engaged in some extensive irradiation experiments involving particular characters. The character which we have used most is the recessive mutant character termed "forked bristles" (f), as compared with the dominant normal straight bristles (F). The evidence is now positive and convincing that the X-rays not only induce the mutation of straight bristles to the recessive forked, but also the precisely opposite type of change: namely, forked bristles to the dominant straight, and abundant controls have shown that it is really the X-rays which are the inducing agent. Similar but less extensive findings have been made in the case of the mutant character called "scute" and its normal alternative "non-scute." The mutations arising as a result of X-

raying are, therefore, not merely destructive changes, not merely losses. If some are losses, others, then, are gains. Doubtless, as in the case of most chemical reactions, most mutations too are changes involving substitutions and rearrangements rather than mere losses or gains.

It should be mentioned that, in addition to the changes in individual genes which X-rays bring about, they also cause—with considerable frequency, as Altenburg and I have shown—breakages of entire chromosomes or strings of genes, accompanied by reattachments of the broken-off fragments to different chromosomes or to the chromosome-remainder from which they were broken, at a different point from before. The rearrangements of genes thus resulting can be analyzed by breeding tests, and at the same time checked up by studies of the chromosomes as seen through the microscope—an undertaking which Dr. Painter and I have been cooperatively engaged upon during the past two years. In this way we have obtained light on the structure and behavior of the genes and chromosomes from a new angle, though space does not permit me to touch upon these results now.[1] There is evidence that such rearrangements of chromosome parts, as well as mutations in individual genes, have occurred repeatedly during the course of natural evolution.

The question may now be raised: to what extent can all these results be regarded as mere curiosities: effects confined to the mature sperm-cells of the fruit-fly, and of little significance elsewhere? In this connection, it may first be pointed out that my results in producing gene mutations in the fruit-fly were immediately confirmed by Weinstein, working at Columbia University, later by others (Hanson, Patterson, Harris, Oliver) at this laboratory, and more recently by Serebrovsky and his colleagues in Russia and by Dr. and Mrs. Timofeëf-Ressovsky in Berlin. In my own work, the treatments were not confined to sperm-cells, but were also applied to the female, and it was found that both the mature eggs and the immature female germ-cells (oogonia) were susceptible to the mutation effect. Harris has recently extended the finding to the immature germ-cells of the adult male. Patterson has found that the early germ-cells of both male and female larvae are likewise susceptible, and also the larval somatic cells. The latter finding, which has recently been announced also by Timofeëf-Ressovsky, opens up a whole realm of interesting possibilities in the production of mutant areas of the adult body, derived from cells of the treated embryo—such effects as might result, for instance, in an individual with eyes of different colors, or with parts of the same eye different. Casteel has been making an anatomical analysis of these latter effects through microscopic sections of the eye. The production of mutations by X-rays is thus a general effect for *Drosophila*, producible in all kinds of cells in that organism. What, now, of the generality of the effect on other organisms?

I need not, perhaps, remind the general reader of the fact that all the principles of heredity so far discovered in the fruit-fly—the favorite experimental object of many modern geneticists—have proved applicable to animals and plants in general. It is more to the point to mention that investigators elsewhere,

[1] The production of such changes in chromosome structure by means of X-rays has been confirmed by Weinstein and later by Serebrovsky by means of breeding tests on *Drosophila*. By means of cytological analysis, Goodspeed and Olson have found similar effects in tobacco, and so have Blakeslee and his associates in the Jimson-weed. The work of the present author and his colleagues, in studying such changes in *Drosophila* by means of breeding tests and cytological analysis combined, has recently been repeated in an elaborate manner by Dobzhansky, with results that are for the most part in striking agreement with those that had been announced by us.

working on other organisms, have now reported results of the same kind as those now in question. Thus, Stadler, at the University of Missouri, was independently attempting to induce gene-mutations in barley and in corn by means of X-rays and radium at the same time that I was doing my first experiments along these lines on flies, and he has found indubitable evidence of the production of gene-mutations in monocotyledonous plants by both these means. Following my work on flies, Whiting has obtained positive results by the use of X-rays on wasps. Blakeslee, Buchholtz and the others of this group have a mass of interesting mutation results from X-rays and radium applied to the Jimsonweed, Datura, that extended the findings concerning lethal as well as visible mutations to dicotyledonous plants. With these so widely separated bits of the living world sampled and all responding positively,[2] it is a reckless critic who still would cast a doubt as to the probable generality of the phenomenon.

Radium rays, like X-rays, produce mutations, because they too, being short-wave-length high-frequency electromagnetic waves of great energy content, release high-speed electrons, and the cosmic rays, which are still more extreme in these same respects, and so release electrons of still higher speed, must necessarily act likewise. For, as Hanson has shown in experiments with radium, the number of mutations produced depends simply on the number of electrons released and the speed and distance they travel (*i.e.*, on the total energy of ionization) regardless of the source of the electrons. Oliver, too, in experiments with X-rays in our laboratory, has obtained evidence that the number of mutations produced is directly proportional to the dosage of radiation used, and Stadler's work points in the same direction. This being true, there being no evidence of a minimal or "threshold" dosage, we are forced to conclude that the minute amounts of natural radiation present almost everywhere in nature—some of it of terrestrial origin, derived from the radium and other radioactive substances in earth, water and air, and a smaller part of it of cosmic origin, apparently derived from the diffuse and distant factories of matter—all this natural radiation *must* be producing some mutations in the living things on the earth. These mutations must be very scattered and very infrequent in proportion to the total non-mutated population, just because the amount of natural short-wave-length radiation is very small at any one place, but, considering the extent of the earth and the multiplicity of living things, the total number of mutations so produced per year must be very considerable. It can, therefore, scarcely be denied that in this factor we have found at least *one* of the natural causes of mutation, and hence of evolution.

How important is this cause relatively? Is it the sole cause of evolution? We do not yet know. Returning to the investigation of the possible effectiveness

[2] The work of Little and Bagg on mice treated with radium, first announced in 1923, is not referred to in the above list, as the results were inconclusive, probably on account of the very small dosage of X-rays used and the breeding technique employed. Only 2 kinds of "mutations" demonstrated to be separate were found among the descendants of the 12 treated parents, and one of these occurred also among the descendants of the 5 control parents. Both may have been "latent" in the stock before treatment. One of these "mutations" seemed to have numerous and variable effects, dependent perhaps upon various "modifiers" hidden in the original stock. It should be remembered by the reader in evaluating these various changes, in kidneys, feet, etc., some of which have been described separately, that all of them together are equivalent to only one mutation, and that the latter may not have been of recent origin. In a repetition of this work with dosage similar to that originally used, MacDowell and his colleagues have found no evidence of the production of mutations. A stronger treatment, or a more extensive experiment, might well be necessary before the effect could be clearly demonstrated.

of poisons and other influences than X-rays, I have, during the past two years, tried out a number of drastic treatments, using a refined genetic technique similar to that in the X-ray experiments, which would have allowed of the detection of lethals and other mutations with far greater ease, and therefore in greater abundance, than in the inconclusive experiments of the past. Included among the treatments were heavy doses of manganese and of lead salts, which had been claimed by J. W. H. Harrison (on the basis of what appeared to me genetically unconvincing data) to produce visible mutations in butterflies. There was also included a repetition of the experiments recently reported by Morgan, Sturtevant and Bridges, who suspected that they had been able to cause visible mutations in the germ-cells of red-eyed flies by injuring their eyes with a hot needle, an operation which was followed by a release of the optic pigment and its distribution throughout the body.[3] But our trials of all these and various other agencies have given negative results, and it is becoming a question where to stop.

On the other hand, it *seems* to be true that other conditions, internal and perhaps also external, accompanying an X-ray treatment, can somehow affect the sensitivity of the cells to that treatment. Thus Stadler finds that the sprouting cells of seedlings have mutations produced in them in much greater abundance, by a given dose of X-rays, than do the dormant cells of seeds, though some mutations are produced in both.[4] Yet in the case of flies both Hanson and Harris, working independently, find that the genes of growing immature male germ-cells are far less sensitive to the mutating effect of radium or X-rays than are the dormant genes in mature spermatozoa.[4] I find that the genes in the spermatozoa of the adult male are also more sensitive than those in the germ-cells of the female, or than those in the germ-cells of the larval male.[4] There seems to be even more difference in their sensitivity to the gene-rearranging effect of the rays than in their sensitivity to the transmuting effect on individual genes. The activity of metabolism, however, varied by starving, and by feeding and mating the female, had no perceptible influence in my experiments, and, as both Stadler and I have found independently on barley and flies respectively, extremes of heat or cold applied at the time of treatment have little or no effect.

Thus the study of the physiology of mutation-production is opening up, though as yet in a very empirical stage. And meanwhile, X-rays and their relatives remain the only prime cause of mutations yet known. Whether radiation furnishes the exclusive motive power of evolution can eventually be ascertained definitely, through painstaking quantitative determinations of the mutation frequencies existing in the presence of extremely minute amounts of radiation. As stated in some previous publications from our laboratory we have experiments projected which we believe will test this question in flies.

Since, however, mutations in general bear all the earmarks of the X-ray mutations, then, even if not all of them have actually been produced by radiation, it seems legitimate to use the readily obtainable X-ray (radium, etc.) mutations as the handle by which to study them. These X-ray mutations are certainly accidental, being produced by ultramicroscopic events, not individually controllable, that take place without reference to the outcome or the advantage for

[3] They announce that they have recently been elaborating upon this work by similar tests on flies with other eye colors, and by artificial injection of substances derived from the eye.

[4] It is probable that a part, at least, of these apparent differences are due to a relatively lower multiplication rate on the part of most mutated immature germ-cells, as compared with the non-mutated ones.

the organism. The natural mutations—*some* of which we know must be due to radiation—are on the average equally as detrimental, and of the same general nature, so far as their effects are concerned, as the X-ray mutations. Can we then escape the conclusion that they are accidental in the same sense, and that specific mutations are therefore not dictated by any "adaptive reactions" or other specific responses of the organism to climate or to any other features of its mode of life?

Due, then, to the tremendously magnified effect which one tiny gene can produce through the processes of growth and development, we have a molar indeterminism, in the origination of genetic variations, resulting from an ultramicroscopic determinism. (We will not quarrel here about whether or not a Heisenbergian "principle of uncertainty" lies beneath the latter in turn.) But now "natural selection" sets to work, weeding out the many disadvantageous mutants here, allowing the multiplication of a few advantageous mutants there, until again from all the maze of variants we have organization returning, advancing, and so, as a statistical consequence, there results a kind of higher molar determinism, finally governing many features of the actual evolution of the species. Thus we are sometimes furnished with such regular sequences of forms as seen in the gradual modification of the horse's foot, or in the shells of some mollusks, where a knowledge of one part of the series enables us pretty closely to compute the rest.

VIII. The Rôle of Multiplication and of Selection in Turning Accident into Order

It does, at first sight, seem incredible that all the marvelous organizations in the living things about us could have been put together by anything partaking of the nature of accident. But we must remember that it did not fall together all at once, and that it was all made possible by that almost magical property which life owes to the gene—the power of multiplication of mutated individuals.

For many millions of years, blind chemical forces must have acted and interacted in early times to build up ever different and more complicated organic compounds and systems of compounds. A turning-point was reached when from these shifting combinations those self-multiplying yet mutable materials which we call genes happened to become formed. From that time on the different genes, or the little systems of organic matter containing an association of genes, would necessarily enter into a destructive competition for multiplication against each other, until, step by step, through mutation, or the alteration of the gene, and heredity, or the multiplication of the gene, the complicated life of the present day became differentiated.

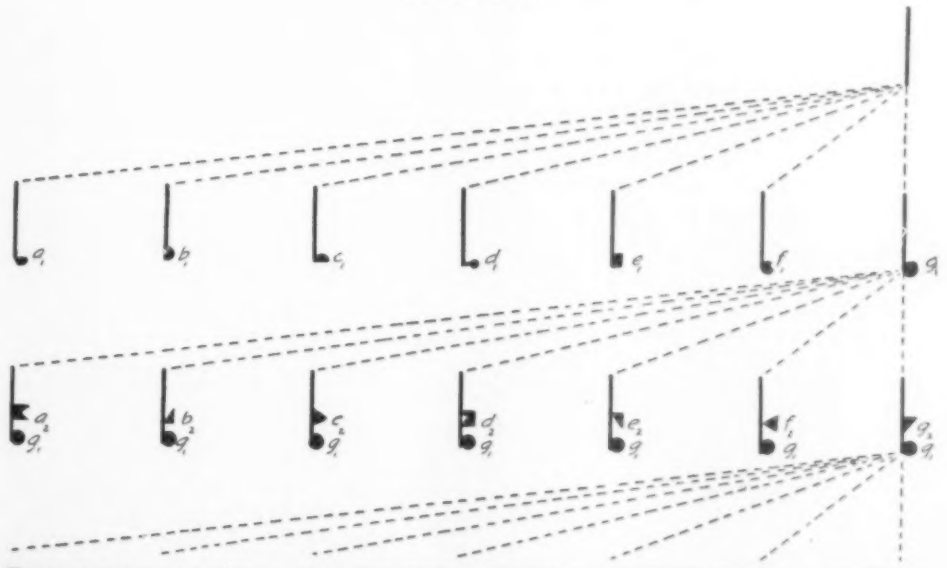
It will be worth our while now to examine more closely just how it is really the peculiar power of multiplication of mutant forms which turns this trick of converting accident into order, by making such very extraordinary combinations of accidents possible as could not otherwise occur. For some reason, this fundamental feature of the matter does not seem to have been fully realized.

In examining the process of evolution, let us be content at first to make our case a very simple one, and to proceed for a while in a very elementary fashion, in order to avoid confusion. Let us first see how just a simple combination of advantageous changes, or mutations, may be obtained in an organism. Suppose we start with some extremely simple organism, represented by the straight vertical line at the top of Diagram I. We will now allow it to reproduce, and allow enough time to elapse so that some mutations or other will have appeared in each of its descendants (they need not be

regarded as first-generation offspring). In our diagram these descendants are shown as vertical lines placed in a horizontal row just below the vertical line representing the ancestral individual, their derivation from which is indicated by dotted connecting lines. We may suppose that multiplication has brought about the existence of seven of these descendants, each with a different "chance" mutation, indicated by a differently shaped spot, and lettered from a_1 to g_1. g_1 may be taken to represent the "good" mutation—the one of an advantageous nature, which is in the path of progress, that happened to occur amongst all the others of a disadvantageous or neutral kind. Now allow a similar length of time to elapse again, in which multiplication and chance mutations take place much as before. The individual with the "good" mutation, g_1, thus multiplies to form seven again, each carrying g_1 (*i.e., the multiplication has involved the variation itself*), but, in addition to g_1, each of the individuals carrying it now carries a second mutation, lettered from a_2 to g_2. Among these second mutations we may again suppose that only one of the seven, g_2, is "good," in the combination in which it occurs. Thus we get a combination, in one individual, of two good mutations, g_1 and g_2, which supposedly have properties that "fit well together," interacting so as to work out advantageously in combination.

Some or all of the other individuals of the previous generation, bearing mutations a_1 to f_1, may also have multiplied. Whether or not they did would not affect our desired result—the attainment of the g_1 g_2 combination—at all, provided only that the g_1 individual itself had been able to multiply and mutate as indicated. If all the individuals of the previous generation had multiplied to just the same extent as the one having g_1 did, there would obviously have been 7×7, or 7^2, or 49, individuals formed bearing some combination of mutations, and of these forty-nine different combinations just one would be the "good" combination—g_1 g_2. Accordingly, with-

DIAGRAM I



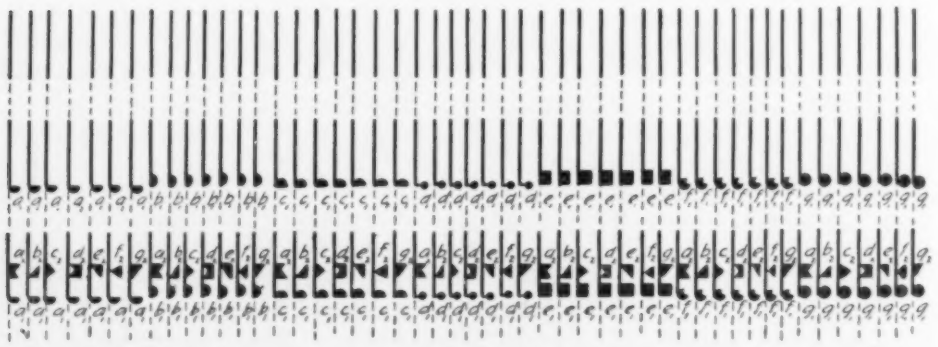
TO ILLUSTRATE THE RÔLE OF MULTIPLICATION IN ALLOWING THE ORIGINATION OF A BENEFICIAL COMBINATION OF VARIATIONS (g_1g_2).

out any "natural selection" or any difference whatever in multiplication rate occurring, there would be one individual in forty-nine having the "good" combination. In still other words, the "chance" of the good combination being present in any particular one of these final individuals, in the absence of natural selection, would have been 1/49. It is to be further observed that, no matter how few or how many of the above forty-nine individuals were actually produced, the ancestors of the g_1 g_2 individual (namely, the g_1-bearing individual and its predecessor, the simple line) had multiplied at the rate required for doing their share in the production of these hypothetical forty-nine individuals.

We may now consider what would happen in the case of some kind of creatures, or objects, which did not have the power of multiplication, but which were otherwise similar to the organisms just discussed, and like them could mutate (or in this case we should simply say, "change"). We may suppose either that these beings produce just one offspring and then themselves die, or that they are potentially immortal and change directly from one form into another. In either case, if their "mutational" possibilities are the same as those of the multiplying organisms previously considered, then we should have to start with seven of them (represented by the seven straight lines at the bottom of Diagram II) to get one having a change equivalent to g_1. But we should have to be provided with seven already bearing g_1 in order to obtain one having g_2 in addition to g_1. Since in the first place only one in seven come to have g_1 (or its equivalent), we should have to start with 7×7, or 7^2, or 49, in order to get the required seven having g_1 (or its equivalent) which would in turn yield the one finally having both g_1 and g_2 (or their equivalents). This is indicated in the diagram. (Here, for convenience in examining the diagram, similar types are grouped together, although chance would scatter them indiscriminately. Also, all forms of "equivalent" type are represented as though identical.)

On comparing these non-multiplying objects with the multiplying ones we then see that, to get a given kind of combination by means of a given incidence of "mutation," we have to start with just as many, in the case of the non-multiplying objects, as, in the case of the others, would have been produced in the end by the entire process of multiplication, if all individuals had multiplied at the rate at which the selected individuals

DIAGRAM II



TO ILLUSTRATE THE MANNER IN WHICH A BENEFICIAL COMBINATION OF VARIATIONS (g_1g_2) MIGHT ARISE IF THERE WERE NO MULTIPLICATION, AND THE NUMBERS WHICH WOULD THEN BE NECESSARY.

did. One out of this total number hence represents the "chance" that our desired combination could have come about purely fortuitously in any particular individual at the end of the given lapse of time, no matter whether the individuals were of the multiplying kind or not. By the laws of chance, if only a few times this total number are given, this combination, or one equivalent to it in "excellence," is practically certain, under the conditions postulated, to be present in one or more individuals.

Organisms, however, represent many more than two advantageous features in combination. By the same reasoning as the above, we may find the chance of obtaining a combination of three features —g_1 g_2 g_3. We may assume again that the g_3 change is in itself, at its time of occurrence, about as rare as either g_1 or g_2 alone was: namely, of the frequency of 1 in 7. It will then be seen that the g_1 g_2 individual must be allowed to go through a period (the third period) of mutation and of multiplication times 7, whereupon g_1 g_2 g_3 will arise. Further, it is evident that the rate of multiplication of the individuals in the line of descent that gave rise to the g_1 g_2 g_3-bearing individual was such as to have given rise to $7 \times 7 \times 7$, or 7^3, or 343 individuals, after this lapse of time, only if all descendants of these ancestors had multiplied at the same rate as they themselves had. In the case of non-multiplying objects, it would have been necessary to *start* with 7^3, or 343 individuals, in order to get a corresponding result—an individual with a rare combination of three advantageous mutually adjusted characters, g_1 g_2 g_3. Generalizing, we may say that if the frequency of an advantageous mutation were 1 in r instead of 1 in 7, and the number of steps involved was s instead of 3, the corresponding total number of individuals would be r^s. All this is, in fact, only a simple application of a well-known and very elementary mathematical principle applying to the formation of random combinations in general.

It is not, however, until we apply this little formula to the natural conditions pertaining to our immediate problem that its full significance for us becomes clear. What shall we take as our "r" (the *rarity* of advantageous, or "organizational" mutations) and what as our "s" (the number of such advantageous mutational *steps*)?

Undoubtedly r changes its value radically at different stages in the evolutionary sequence, but it would seem quite conservative to represent r, in general, as being as small as 100. In other words, it seems likely that at least 100 mutations must usually occur before one occurs of such a special type that it could take part in the improvement of the life-organization. In flies (*Drosophila*) we find that there are something like ten times as many "lethal" and "semi-lethal" as ordinary visible mutations, and even among the "visibles," the vast majority reduce vitality or lessen the chances of survival in one or more ways. It is certain that not 1 in 100 detectable mutations is advantageous in flies; in fact, for all we know, the number may be more like 1 in 100,000.

In the case of s there are almost equally wide limits of uncertainty, but again we may arrive at a safe minimum figure. In flies I have shown that there are at least 1,500 different genes, and probably many times that number. There must then have been at least 1,500 different mutations to produce these genes from their predecessors. This figure, however, seems absurdly small in view of the great complication of a fly's anatomy, physiology and developmental processes. It is very likely, then, that there are many more genes than 1,500 and that each gene has had a history of numerous mutations, which step by step

have differentiated it from one original type of gene. Considering too that man is certainly much more complicated than a fly, we might boldly guess that there may have been a million or more advantageous mutational steps in his ancestry (this would allow, say, 50,000 genes, in each of which, on the average, 20 mutational changes had occurred). Let us first, however, take s, for man, at the undoubtedly far too low minimum value of 1,500, and r at 100.

Our total number, r^s, thus becomes $(100)^{1,500}$. That then is the minimum number of individuals we should have to start with, in the case of non-multiplying objects, to arrive, by "pure chance," at one having the complication and perfection of organization of a man. We shall examine later what the size of this number implies. It is also the minimum number which the multiplication rate of the ancestors of man would have led to, if all the descendants of these ancestors had continued multiplying at this same rate, *i.e.*, without selection.

It might here be inquired whether such a rate of multiplication would have been possible or likely to occur in these ancestors, in the time during which life has existed on the earth. We know that life has been here for a period having an order of magnitude of something like a thousand million years, that is, a million millennia. If there were only 1,500 mutational steps in this time, that would make only one step in each 670,000 years. Our postulate, $r = 100$, requires that an individual in the line of descent of man should multiply at least a hundredfold between each advantageous mutational step that became incorporated in the germ-plasm, and the next one. It is obvious that far more than this much multiplication could easily happen in 670,000 years. For it only takes seven doublings to make a hundredfold multiplication, and the slow-breeding modern European has been able to double his population merely in the space of the last century. The multiplication organisms, then, would have no difficulty in fulfilling these conditions.

Suppose, now, we try the more extreme figures, $r = 10{,}000$ and $s = 1{,}000{,}000$, so that r^s becomes $(10{,}000)^{1,000,000}$. To go through a million mutational steps in the course of a million millennia would require one mutation to become incorporated in each millennium, or thousand years. It would also be necessary for the selected type of mutant to multiply by 10,000 during this period of time, and meanwhile to undergo another mutation. There can be no reasonable doubt that a millennium is plenty long enough for many another mutation to occur, in all the descendant germ-plasms, but how about the large amount of multiplication here required? Most lower organisms go through a generation in not over a year's time, and are able, when given the opportunity, to multiply many fold in a single generation. If, however, we suppose that the "select" individuals, those with "good" mutations, only increase in numbers, on an average, by 2 per cent. in each generation, then, at a year to a generation, each such individual would increase from unity to nearly two hundred million in the course of a thousand years. This is far beyond our requirement of 10,000 times.[5] Thus we see that the multiplying organism could probably do much better than accumulate 1,000,000 mutations during the time that life has already existed here, even though each mutation represented the selection of the best in 10,000.[6] Multiplication

[5] A 1 per cent. increase, per generation, would give a multiplication of about 14,000 times in a thousand years.

[6] Allowance must, however, be made for the fact that accidental elimination wipes out the great majority of mutant genes within a few generations after their origination. That is, the process of "differential multiplication" or "selection" is very haphazard until a sizeable number of individuals with the mutant gene

hence has probably afforded the opportunity of obtaining an individual that represents a chance of even less than one in $(10{,}000)^{1{,}000{,}000}$.

It should be noticed that, for the evolution of the multiplying organisms, the only two required conditions have been the occurrence of "chance" mutations (which need include only a very minute proportion of "good" ones), and the ability of the individuals carrying these "good" mutations to multiply to an extent which, within the limits of one generation, need be only extremely limited, but which, continued over a great lapse of time by something akin to a geometric progression, because prodigious indeed. In this process the rôle of "natural selection" consists in just this: that by the elimination of the "unfit" individuals, or the restriction of their numbers, room is made to *allow* the multiplication of the others at the rate required to provide the "chance" for the remarkable 1 in $(100)^{1{,}500}$ or 1 in $(10{,}000)^{1{,}000{,}000}$ combination to appear. In other words, selection merely gives opportunity for the multiplication to proceed in the adaptive or better-organized lines at such a rate as would, if uniformly continued throughout, have given the total which automatically contains the "desired" combination.[7]

If we imagine a world in which, through some sort of miraculous intervention, the combinations which we now call the "unfit" are all allowed to persist and reproduce like the others, the evolution of the "fit" would nevertheless proceed much as in our own world, so long as they too were granted the opportunity to multiply as they do here. Thus "natural selection" would not be necessary for their production. But these "fit" or "well-organized" individuals, and lines of individuals, though in absolute numbers as numerous as here, would necessarily form but an infinitesimal fraction of all the unthinkably vast horde of other combinations that had come into existence simultaneously (just as in the hypothetical case of the non-multiplying beings, in which, if we started with this same final number to begin with, we would eventually find included among them by sheer accident creatures as complexly adapted as ourselves). The fact that the fit owed their existence to "chance" would then be obvious, owing to the relative smallness of the minority in which they existed. In our world, the misfits are largely nipped in the bud, and yet, in the sense just explained, we see that we too are really but the vanishingly small, viable, visible fraction of a stupendous ghostly army of potential creatures, involving a total of $(100)^{1{,}500}$ to $(10{,}000)^{1{,}000{,}000}$, or

happens to become established. This is, of course, very much more true in the case of recessive mutants than of dominants, unless there is very much inbreeding. (One effect of this would be to weight the scales of selection heavily in favor of dominants, leaving the recessives as the "abnormal" forms.)

There is another process which works in the opposite direction to the above, *i.e.*, which hastens the "establishment" of advantageous mutations in the selected lines of descent. This process is the formation of new combinations of genes occurring in sexual reproduction. For the sake of simplicity it has been ignored in the above account. By its means it is made possible that various different advantageous mutant genes which have been multiplying simultaneously in parallel, in as many different (but partially overlapping) sections of a population, can be finally combined into one line of descent. Thus many more mutant genes can be accumulated into one (final) line of descent, in a given length of time, than if all the mutational events and selections had to occur successively in a single line. Owing to this factor, the number of mutational steps may well have been of a considerably higher order of magnitude than 1,000,000.

[7] At the same time, we should not minimize the importance of natural selection in determining which individuals will be allowed to multiply, and, therefore, which of the myriads of possible directions evolution will be allowed to take. The old analogy to the process of pruning a tree is very pertinent in this connection.

maybe many more, possible combinations of misfits.

A little consideration may now be given to the size of this theoretical total number, to show that actually it would be quite impossible of physical attainment. Consequently, if there were no selective elimination, multiplication could not possibly have gone on to anything like the required extent in the "good" lines. Likewise, if we had had to do with objects that could not multiply, there could not possibly have been anywhere near enough of them provided in the beginning to allow an organization comparable with that of a higher or even lower organism to be formed in any of them by mere "chance."

Even the admittedly far too low minimum figure, $(100)^{1,500}$, is of staggeringly great dimensions. If there were this many beings actually produced, then, even if each being were as small as an electron, and all the beings were packed tight together, there would not be nearly enough room in the entire Einsteinian universe, packing them in a hundred times beyond the limits of the farthest visible stars and spiral nebulae, for even an insignificant tittle of them. If we allowed each of these packed "creatures" to go through its entire evolution, of 1,500 steps, in the millionth part of a second, and then substituted another "creature" for it and gave the latter a like chance, and so on for a quintillion years, we still should not have begun to make any appreciable impression on the above number. Neither should we if, in addition, each of these packed beings of electron size, present for each instant, were itself expanded into an entire Einsteinian universe, and each of these universes were then crammed with beings of electron size in its turn. In fact, we might continue thus expanding and subdividing worlds time and again without approaching sensibly close to the required figure.

Hence, in beings without the property of multiplication of variations, and its corollary, natural selection, any such incredible combination of accidents as ourselves would have been totally impossible of occurrence within the limits of practically any number of universes. We are thus really justified in feeling that we could not have fallen together by any accident of inanimate nature. But, given the power of multiplication of variations resident in "living" things, due to their genes, and all this is changed, and we are enabled to enjoy the benefits—such as they may be—of being the select of the select, such as it would have taken a surpassingly vast number of worlds to search through, before our match could be found anywhere by the ordinary processes of chance. In that way, I hope, the metaphysician may reach his "philosophical satisfaction" in the contemplation of his own frame and of the processes whereby it came into existence.

IX. The Task Ahead

The biologist is not satisfied to stop there, however. The real problems of the generation of new living things are only commencing to open up. The occurrence of variations, although "accidental" in the sense just explained, nevertheless is subject to a mechanism, our knowledge of which is as yet in its most elementary stage. Moreover, the biologist of broader view is not so well satisfied with his own frame. He knows that there never has been any one objective in the course of evolution, and that every creature, including man, is only on probation, and may give way before another in which a more advantageous succession of mutations happens to come along. The vast majority of species, in fact, have perished along the way, and only a relatively few survive, through change, to form the continuing threads of life that branch out again.

Man, however, is now the first creature in the world to have this advantage—he has reached some understanding of this process of evolution in which he has hitherto been caught and blown about, and with understanding there frequently comes some measure of control. He can now produce mutations for the first time, and I have no doubt he will soon experiment with this knowledge and in time by its means greatly improve and alter the forms and functionings of those domestic animals and plants which he has taken under his care. Look at the motley shapes of flies that have been made in the laboratory, and you may more readily appreciate the possibilities thus presented.

Despite these advantages, we are today almost as far as ever from producing to order the exact mutations which we want. Enough, for the plants and animals, simply to produce a great many mutations and then take our choice, as nature has done in a far slower and more halting fashion. But the research must go on. Man must eventually take his own fate into his own hands, biologically as well as otherwise, and not be content to remain, in his most essential respect, the catspaw of natural forces, to be fashioned, played with and cast aside.

If we have had a billion years of evolution behind us, and have advanced from something like an ameba to something like a man, then, in the many millions of years which are still in store for our world, why may we not be able to make a further great advance, perhaps far greater even than this, because under our own increasingly intelligent guidance? At least, if we are men as we like to think of men, challenging all things, we must make the attempt, and die fighting if need be, with our eyes open.

BRIDGMAN'S NEW VISION OF SCIENCE

By Professor ALBERT P. WEISS
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It is time to inspect critically the exact significance of the claims that the recent developments in subatomic physics will make it necessary to revise the fundamental assumptions underlying science, especially biology, psychology and the social sciences. In the March, 1929, issue of *Harper's Magazine*, Professor P. W. Bridgman reviews some of the recent developments in physics and indicates that Newtonian physics has "presented to the mind a sublime picture of the interrelatedness of all things; all things are subject to law, and the universe is in this respect a unit."[1] This picture he believes must be exchanged for one which shows that "nature is intrinsically and in its elements neither understandable nor subject to law."[2]

When the social scientist or psychologist tallies off the achievements in physics, chemistry, biology, medicine, during the last one hundred years and is then told that this development or evolution is based upon illusion one may wonder whether it is not the physicist who has the illusion. The social sciences are undoubtedly swinging towards the methods of classical physics as supplemented by the recent developments in statistical theory. Before trying to shift to the principles implied in the newer subatomic physics it may be well to scrutinize the behavior of the physicist himself and learn to what extent his discoveries are the product of his own past behavior and the cumulative effects of the social organization of which he is a part.

It may be that the physicist is overestimating his ability as a psychologist. From the standpoint of physical change, law and order do not exist in the external world. Things only happen, either together or one after another. It is the individual who designates the events as orderly or disorderly. The fact that the physicist has excluded from his researches most of the things that are not uniform has blinded him to the fact that this is after all a very irregular universe even in its superatomic manifestations. If there is anything less "understandable" than large-scale social interaction, it remains to be discovered. Compared with international movements the convulsive jerks of electrons are simplicity itself.

The development of natural science in the past was largely a matter of extending the range of the sense organs through microscope, telescope, audion tube, etc. As long as the sensory limit is above that of the cells out of which the sense organs themselves are made, it is possible for the sensorimotor system of the individual to react to some aggregates of electrons and protons (in the environment) through other aggregates of electrons and protons (in the sensitive cells of the eyes).

Now, however, the observational range has reached a degree of magnification where the physicist must use one electron to observe the movements of another electron. The term *observe* actually means to *react to* (a bodily movement of some sort). The simplest recording reaction (pointer reading, verbal or written report, etc.) involves billions of electrons and protons, and it should therefore not surprise us that the home life of an electron is still rather obscure. Experimentally we have the problem of detecting an energy relationship between

[1] P. 443.
[2] P. 444.

two electrons as a function of the energy relationship between billions of atoms (our sensorimotor system). It may be that we have actually reached the experimental limits, but the astounding thing is that we have achieved so much. Instead of saying that "nature is neither understandable nor subject to law" would it not be clearer, although less dramatic, merely to admit that the human mechanism is approaching the experimental limit of discrimination and that no theory has yet been formulated which may be used as an extension or substitute, for the direct experimental reactions of the physicist.

Professor Bridgman supports his thesis of "non-understandability" from an illustration taken from classical mechanics.

> An expert billiard player can, by proper manipulation of the cue ball, make the two balls rebound from the collision as he wishes; this involves the ability to predict how the balls will move after collision from their behavior before collision. We should expect by analogy to be able to do the same thing for a collision between a bullet of radiation and an electron; but the fact is that it never has been done and, if our present theories are correct, in the nature of things never can be done. It is true that, if some one will tell me how the electron bounces away, I can tell, on the basis of the equations given by Compton's theory, how the bullet of radiation bounces away, or conversely; but no one has ever even been able to tell how both will bounce away. Billiards, played with balls like this, even by a player of infinite skill, would degenerate into a game of pure chance.[3]

The very obvious answer to this problem is that under the conditions given, no billiard player at all could be developed. To develop infinite skill in billiard playing the player must be able to *see* all the balls that are involved in the interaction. Suppose he is obliged to play with balls of such a nature that as soon as two balls collide, one of them immediately becomes forever invisible. Certainly such a game is one of pure chance, but it is not billiards. Yet this is just what happens in subatomic physics. An electron can not be illuminated so that it will remain visible throughout its entire path. The source of the illumination is itself a whole series of billiard balls thrown against the particular ball which is used in scoring the game. Under such conditions is there a game of billiards? To conclude further that this demonstrates that there is no uniformity underlying whatever interactions do take place between electrons and light darts is not warranted. Visibility to some physicist is not an essential condition for electron-proton interactions, although visibility is an essential condition for learning to play billiards. The only conclusion warranted by the facts is that one can not play billiards with electrons.

With the formulation of Heisenberg's "Principle of Uncertainty," Bridgman believes that a new note is being introduced into theoretical physics and that this principle is "fraught with the possibility of greater change in mental outlook than was ever packed into an equal number of words."[4] This is a wider mental outlook for the physicists surely, and it signifies that theoretical physics is just beginning to realize the social basis of some of its findings. The science of physics is a social development. It is the product of the interaction among many individuals, and it is not surprising that even its most firmly established principles show traces of a variable factor which is derived from the variability of human behavior.

A curious instance of a type of confusion hardly to be expected from a scientist is encountered in Bridgman's deduction from Heisenberg's principle. The statement of the principle is given as follows:

> Heisenberg's principle states, on the other hand, that the ultimately possible accuracy of our measurements is limited in a curious and

[3] P. 446.

[4] P. 446.

unsuspected way. There is no limit to the accuracy with which we can describe (or measure) any one quality in a physical situation, but if we elect to measure one thing accurately we pay a price in our inability to measure some other thing accurately. . . . The meaning of the fact that it is impossible to measure exactly both the position and velocity of the electron may be paradoxically stated to be that an electron can not have both position and velocity.[5]

Is not the paradox "that an electron can not have both position and velocity" merely a verbal paradox? Electrons move even though the characteristics of their movements can not yet be formulated by some physicist. All that is scientifically justified is the statement that the position and velocity of an electron can not both be measured at the same time. This, however, is only an experimental limitation (perhaps a permanent one) because our present methods of measurement distort one of the variables we are measuring. This occurs very frequently in psychology. If we wish to learn how rapidly an individual can press a key after a sound signal is given, the mere fact that we have measured the so-called reaction time changes the rate of the subsequent reactions. But the psychologist does not conclude from this that a person has *no* reaction time or that measuring the reaction time is "meaningless." He merely reports the conditions under which the reaction times were measured and their degree of variability. In biological, psychological and social measurements the experimental conditions under which the measurements are made often distort the measurements.

Bridgman frequently makes use of the term "meaningless" in a way that is bewildering to a critical reader. To quote directly:

A body has position only in so far as its position can be measured; if its position can not in principle be measured, the concept of position applied to the body is meaningless, or in other words, a position of the body does not exist. Hence if both the position and the velocity of the electron can not in principle be measured, the electron can not have both position and velocity; position and velocity as expressions of properties which an electron can simultaneously have are meaningless.[6]

Instead of saying "a position of the body does not exist" the only scientific statement that is warranted is the one already made, *viz.*, "its position can not in principle be measured." Again there is no justification for affirming that before a body can exist it is necessary for some physicist to formulate its position. The "hence" clause only means that if the measurement of the position of an electron is dependent on light darts it may be forever impossible to formulate its position at some specified instant because the only way we now have of measuring the position of an electron is through the indirect action of light darts on the sensitive structures in the retina of the eye.

There is nothing meaningless about this. It is merely the statement of an experimental limitation. Such limitations are so frequent in the biological and social sciences that they are regarded as a matter of course. However, it does not follow from this that the experimental method must be abandoned. In fact, very few physicists have themselves been influenced by the limitations. There seems to be no marked decrease in physical experimentation, and the experimenters are not relying on any "principle of uncertainty" in preparing their set-ups.

One of the statements which Professor Bridgman makes does represent a change in the point of view of the physicist which is very significant, at least for the psychologist. He states, "The physical properties of the electron are not absolutely inherent in it, but involve the choice of the observer."[7] This introduces an individual and a social com-

[5] P. 446.

[6] P. 446.

[7] P. 446.

ponent into theoretical physics which has been too long ignored. The term physical properties is acquired by the physicist during his lifetime and through his social interactions with other individuals (teachers, colleagues, etc.). The physical properties which are assigned to an electron depend on the physical (anatomical and physiological) properties of the physicist. He can not assign properties that do not act upon his sense organs. This means that one limitation of the physicist's definition of an electron is determined by his own sensorimotor structure and function. In this sense the electron is the verbal invention of some physicist. This symbolism may then be adopted by other physicists.

This brings us into psychology. If the electron is an invention (a verbal formulation of a hypothetical structure of some sort) how did it come to be adopted by other physicists? The psychologist would say that the verbal formulation (symbol) may act as a stimulus for other physicists so as to make it possible for them to continue research behavior which has been hampered because of theoretical limitations. From this standpoint "an electron" is only the name for verbal statements which stimulate physicists to renewed activity within the sphere of their vocation or profession. In the social organization such activity will survive over those stimulating conditions (an inadequate theory) which lead to inaction. In general, research activity produces better conditions for the survival of the members of a social organization. In addition to the biosocial advantages of such an invention, subsequent experimentation may actually lead to a verification of the hypothesis.

The fruitfulness of a purely verbal formulation of a hypothetical principle is well illustrated by the physicist's ether. Most physicists are agreed that the concept of the ether is about one of the most contradictory concepts (from the standpoint of logic) that has ever been formulated. But this did not prevent its use in theoretical physics. If the social character of scientific behavior is recognized then the ether hypothesis was only a verbal stimulus for activity (research in physics) which was hampered without the hypothesis.

Another way in which Bridgman's "choice of the observer" enters into physical theory is through his implicit assumption that a verbal formulation must have a fundamental "reality" back of it. Specifically, do electrons and protons have properties other than those assigned to them by some physicist? If we accept the verbal or social character of the electron hypothesis, of course its elements (the electrons and protons) have only those properties that are assigned to them. However, other physicists may find one man's hypothesis of greater utility by adding to or subtracting from the assigned properties. If the experimental results (Eddington's pointer readings) that are secured with a given hypothesis are nearly identical for all physicists, one way of expressing a high degree of uniformity among the physicists is by classifying the hypothetical properties as "real" properties. However, it should be clear that the term "real" is only a name which indicates the degree of uniformity in the behavior of the physicists (not in the properties of the electrons). It would be clearer, however, not to use the term "real" at all, but merely indicate numerically the averages and deviations of the experimental findings (that is, the pointer readings).

This problem often manifests itself in a more popular form. If the electron and proton are merely verbal formulations (symbols) invented by some physicist, were there any electrons before they were invented? The obvious answer is that since the electron is a verbal inven-

tion, the *invention* did not exist before it was invented. And if it is asked, has the composition of matter changed since electrons and protons were invented, the answer is that it has not. However, the physicist's reactions to matter have changed very much. Some physicists are now reacting to what at one time was called matter in a different way (performing entirely different experiments) than they did fifty years ago. It is the physicists who have changed. The manual and physiological reactions to matter are practically the same as those of individuals living a hundred years ago. It may be that the new responses which the physicists are developing will modify the behavior of all other individuals and it may be that these changes are very significant for survival. To assume an underlying reality having certain absolute properties may be experimentally and technically useful in organizing and classifying human behavior, but such a "reality" is merely a name for specific verbomotor responses that have been acquired by the physicist during his lifetime.

From the psychological standpoint Bridgman's use of the terms, cause, effect, determination, prediction, seems unclear. To quote directly:

> When we say that the future is causally determined by the present we mean that if we are given a complete description of the present the future is completely determined, or in other words, the future is the effect of the present, which is the cause. This causal relation is a bilateral relation; given the cause, the effect is determined, or given the effect, the cause may be deduced. But this means, in the particular case that we have been considering of collision between a bullet of radiation and an electron, that the causal connection does not exist, for if it did the way in which the electron rebounds after the collision would be determined, that is, it could be predicted, in terms of what happens before the collision. Conversely, it is of course impossible to reconstruct from the way in which the electron and the radiation rebound the way in which they were moving before collision.[8]

[8] P. 447.

In this quotation Bridgman seems to say that unless it is possible to formulate what will happen, nothing will happen. It would be more correct to say, if it is impossible to formulate what will happen, prediction is impossible. This is, of course, obvious, because in this case the terms "formulate" and "predict" are synonyms. He is quite right, however, in pointing out that all that is implied by the terms cause and effect is a certain relation between the elements in a temporal series of events. Electron-proton combinations are constantly changing. The change which precedes is arbitrarily given the name of "the cause" and the change which follows is given the name of "the effect." In the widest extension of the use of the terms cause and effect in the modern sense, any one specific event which is occurring now has as its invariable antecedents everything that has ever occurred in the past; and everything which is occurring now is a partial cause of any single event, even the most remote, that will happen in the future. That is to say, the activity that I am now performing in writing this article and the activity of the reader in reading it are partial causes of what will happen on the sun two thousand years from now. The effect may not be of any practical or social significance and it may even elude the finest measurements, but this does not demonstrate that there is no effect.

To give the terms greater specificity science usually limits the term cause to changes such that if they did not occur, the effect would not appear. If the series of changes is of the type that occurs in conformity with a known mathematical equation it is proper to speak of prediction, but such an equation can not be formulated unless a sufficient number of points are established to indicate its geometrical classification as a straight line, parabola, sinusoidal function, etc. After the degree of reliability

has been established either from empirical or hypothetical data it is possible to extrapolate or extend the curve forward or backward. This is all that is meant by prediction. However, this should not be confused with determination. Some events seem to occur in a regular sequence whether or not some physicist is able to formulate the equation which describes this sequence. The uncertainty of electron movements merely demonstrates the fact that no equation which connects the electron and radiation has yet been formulated. It may even be impossible to formulate one on account of the technical difficulties and the limitations of our sense organs, but there is no justification for saying that electrons will continue to act in this apparently helter-skelter fashion until some physicist invents an equation according to which they may henceforth regulate their behavior.

A more concise summary of the baffling character of the principles of subatomic physics is given in the quotation:

> The same situation confronts the physicist everywhere; whenever he penetrates to the atomic or electronic level in his analysis, he finds things acting in a way for which he can assign no cause, for which he never can assign a cause, and for which the concept of cause has no meaning, if Heisenberg's principle is right. This means nothing more nor less than that the law of cause and effect must be given up. The precise reason that the law of cause and effect fails can be paradoxically stated; it is not that the future is not determined in terms of a complete description of the present, but that in the nature of things the present can not be completely described.[9]

As Bridgman here uses the terms cause and effect they imply a practical or social distinction. A cause in the social sense usually means that there are a minimum number of conditions which must be fulfilled before a number of specified conditions will follow. In other words, from the social standpoint the cause and effect relationship usually refers to the problem of environmental control. In biological experimentation, for instance, it is impossible to enumerate and describe *all* the conditions which are the antecedents of some observed effect. However, from a statistical analysis it is possible to determine what antecedent conditions are required before a given galaxy of conditions called the effect will appear. While complete prediction requires a complete description of everything that has preceded, yet for practical prediction the number of antecedents to a limited effect is well within the possibilities of human achievement. The paradox, therefore, that the future is unpredictable because the present can not be completely described, again merely affirms the limitations of the sensorimotor structure and function of man. However, it is this same sensorimotor structure which, through its verbalized reactions, does invent a symbolic set of stimuli through which the movements within the individual may be regarded as a correlational function of everything that has happened, is happening and ever will happen.

Theoretical physics is the product of human interaction, it is not a "reality" beyond human behavior. Professor Bridgman seems to understand these limitations very clearly but when he says that "This inevitableness is rooted in the structure of knowledge" he is introducing a term (knowledge) which can not be said to have achieved a scientific clearness that is at all commensurate with the clearness of such terms as electrons, entropy, relativity, etc. The physicists have not yet learned that the whole question of the nature of the psychological elements and the status of psychological theory is very much a controversial matter at the present time. This uncritical acceptance of psychological conceptions is well brought out in the following quotation:

> The result of all this pondering has been to discover in the principle [that the universe is governed by pure chance] an inevitableness,

[9] P. 448.

which when once understood, is so convincing that we have already almost ceased to kick against the pricks. This inevitableness is rooted in the structure of knowledge.[10]

Professor Bridgman sees very clearly that in the last analysis what goes on in the universe can only be derived from the changes which occur within his own body. In other words, the individual can get into contact with the universe only in so far as his own movements are functions (in the mathematical sense) of movements that have occurred in the external world. Necessarily the degree of functional relationship between my body and the external movements will depend upon how accurately my movements are functions of the external movements, and the degree of accuracy in reacting to external movements is limited by the fineness or coarseness of the structure of my own sense organs. This can be generalized by saying that the individual movements are functions of external movements. Most of the difficulty arises when the physicists uncritically accept such terms as knowledge, mind, consciousness, awareness, as representing entities which are in some way entirely different in structure and function from the processes they are investigating.

This introduces the assumption that there are two universes: one of mind and one of matter. It may be that this is the simplest assumption to make, but at least it should be recognized as an assumption to which there are alternatives. There are many practical considerations which make the assumption of an external world highly probable. The line between the external world of movements and movements within my own body can not be sharply drawn. All bodily movements are muscular movements, that is, contractile effects in muscle fibers. However, these contractile effects are the products of nervous processes or chemical reactions occurring in the nerves which lead to the muscle fibers. These nervous processes in turn are the products of chemical or mechanical processes in the sense organs, and the chemical or mechanical processes in the sense organs are the resultants of movements in the stimuli (of the external world) which act on the sense organ. All this represents a continuum of the type of a differential equation in which the division between one stage and the next is not a sharp line but only approaches a limit. We can not say where external stimulation ends and internal activity begins; we can only approach the limit of the different energy transformations between sense organ, nerve and brain. In the same way further arbitrary distinctions are made between brain and muscle contraction. These may be rather carefully defined as the approach toward some mathematical limit, but they can not be so carefully established empirically or experimentally.

Thus far it has been tacitly assumed that human behavior is a form of motion. For theoretical physics the behavior is the totality of these movements in the various physicists which make up the experiments, records and literature of theoretical physics. Now just where in this series shall the non-physical principles of awareness, mind, knowledge, be introduced? When the physicist speaks of the formulation of his problems as "rooted in the structure of knowledge" he assumes that the psychologist is able to transform the professional movements of the physicist into mental states which have none of the physical properties of the verbal and experimental activities of the physicist. However, there is very little agreement among the psychologists themselves as to what is to be included under such terms as knowledge, consciousness, awareness, etc. In fact, many psychologists have reached the conclusion that it is hopeless to try to give these

[10] P. 448.

terms a scientific status. Such a statement as "the fundamental datum of all knowing is consciousness" sounds reasonable and clear. But this is only due to the fact that such statements have been reiterated so often that there is now no longer a critical analysis of them. Certainly not by the physicists. Scientifically the statement is only a verbal reaction which is a symbol neither for a fact nor for a relationship. It is only a habit of speech that individuals have acquired under certain social (non-scientific) conditions.

When physicists reduce electrons and protons and the interactions between them to conscious mental states they should understand that no one knows what a mental state is, or what the mind is. To insist that it is understood intuitively is simply substituting loose literary habits acquired in early life for the more rigid habits of scientific analysis. It would be a wholesome adventure for those physicists who try to generalize beyond their own researches to try actually to find a definition, description or explanation of mind, awareness, consciousness, meaning, feeling, etc., which they regard as in any sense scientifically clear and satisfactory. As a psychologist the writer should perhaps be ashamed to admit this, but his own efforts at trying to do just this thing have left him no alternative.[11]

The physicists who are now writing on the philosophical or psychological aspects of modern physics are using a psychology which they acquired during their undergraduate years. The psychology of to-day is no more like the psychology of twenty-five years ago than the physics of to-day is like that of the nineties. The physicist may throw up his hands in despair at the confusion which confronts him in psychology, but this does not warrant adding his own even less scientific conception of mind to any of those which he may have rejected. Modern psychology is a closed field for the physicist as such. He may indulge in certain literary speculations and poetic flights, just as any one else may do, but he is no more an authority in the field of human behavior or social organization than any popular writer. More concretely, just what is to be included under the terms "subconsciousness," "instinctive," "experience," in the following quotation?

> The new situation can not be adequately dealt with until long continued familiarity with the new facts produces in our sub-consciousness as instinctive a grasp as that which we now have of the familiar relations of every-day experience.[12]

Another example of uncritical analysis is brought out by the statement,

> The physicist thus finds himself in a world from which the bottom has dropped clean out; as he penetrates deeper and deeper it eludes him and fades away by the highly unsportsmanlike device of just becoming meaningless.[13]

That is to say, "meaningless" for the physicist. There can be no sportsmanship at all when one of the players does not know the rules of the game. In this case it is the physicist himself who has not learned how he has acquired the tools (rules) of his own profession.

Bridgman dreads the effect of the new conceptions of physics on the man in the street. To quote directly:

> But doubtless by far the most important effect of this revolution will not be on the scientist, but on the man in the street. The immediate effect will be to let loose a veritable intellectual spree of licentious and debauched thinking.[14]

It is well to point out that the spree is already on and that it is by no means limited to the man in the street. For the

[11] For a more detailed account of the writer's views see his "A Theoretical Basis of Human Behavior," R. G. Adams and Company, Columbus, Ohio, 1929.

[12] P. 449.

[13] P. 450.

[14] P. 451.

psychologist the problem presents a very interesting phase of what happens to the scientist when he is suddenly required to change the habits of a lifetime. The physicists for at least two generations had all their problems nicely labeled and theoretically solved. Something new happened. Roentgen discovered invisible radiations and this started a new line of research. One discovery followed another in rapid succession. Not only was the complacency of the physicists markedly disturbed in their own field but they are insisting that all the other sciences should be equally apprehensive. Surely, they say, if we, the salt of the scientific earth, are so disturbed it is only proper that ordinary persons should go into convulsions. We have lost our bearings, consequently the whole world is about to collapse.

In the biological and social sciences development has been so rapid that these scientists have developed habits which have tended to stabilize their behavior in the presence of profound economic, industrial, political and social changes. This sort of thing is expected and the new developments leave the scientist quite calm and collected and with a realization that he must assimilate the new findings into his old ways of looking at things as rapidly as possible. Sometimes the old way must be completely discarded. He complains about this a bit, depending upon his age, but in the end he does change. Perhaps this is all that is bothering subatomic physics. The change was a little too abrupt for the degree of complacency that the physicists had developed. The last paragraph of Bridgman's article illustrates how completely physics has failed to consider even the most elementary facts of human behavior.

> And in the end, when man has fully partaken of the fruit of the tree of knowledge, there will be this difference between the first Eden and the last, that man will not become as a god, but will remain forever humble.[15]

Bridgman is humble now, and there are a number of other physicists who feel the same way, but this is because they are baffled by the complexity of the physical situation which must be fitted into a social system. Humility is the attitude of the conquered. Man triumphant has never been humble. The marvelous development of industry during the last half century has not developed humility in the business man. Even the physicist will again be proud when certain strained relations between subatomic and superatomic behavior will have been arbitrated.

[15] P. 451.

THE SEARCH FOR MINERAL DEPOSITS

By FRANK EBBUTT

BRITANNIA BEACH, B. C.

No one has, perhaps, realized the importance of minerals to human welfare and to progressive civilization more than modern man. This realization, both on the part of many individuals and by the larger mining companies and interests, leads to a more or less constant though often haphazard search the world over for ore deposits.

The importance of this search for minerals can not be overestimated. Mining is one of the foremost basic industries, and its perpetuation is absolutely dependent on the discovery of new ore reserves. Almost every individual or group engaged or interested in this search for mineral deposits will admit that it is constantly becoming more and more difficult and more costly to find ore bodies of sufficient merit to warrant development.

In the not very distant future the industrial life of America will very largely depend on the ability of the mines to maintain the supply of its many and varied metallic wants. At the present time almost any one at all conversant with the mineral resources of the North American continent, or, for that matter, of the world, can make a fairly accurate forecast as to the life of the known ore reserves for the various minerals. In some cases the predicted life of the known reserves is almost startlingly short, especially when looked at in the light of present consumption and possible or perhaps undoubted increased future needs. On the other hand, no doubt, substitutes for some or even many of the minerals demanded by industry will be found and used by the time the various minerals reach the point where they can no longer be mined at a profit.

Because mining is absolutely dependent on ore finding, ore finding must be recognized as of first importance not only to mining but to all industry, especially manufacturing, which is so dependent on a cheap and unlimited supply of many minerals. Because industry, which spells prosperity and perhaps even civilization, is so dependent on the supply of minerals in their

INDIAN IN SPRUCE BARK CANOE

LIARD RIVER, NORTHEASTERN BRITISH COLUMBIA.

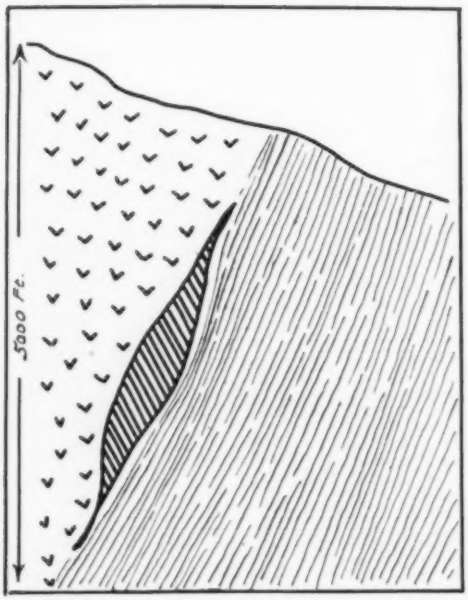


Figure 1.

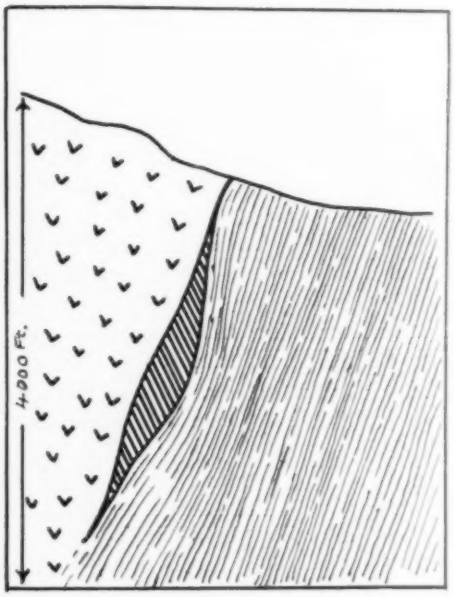


Figure 2.

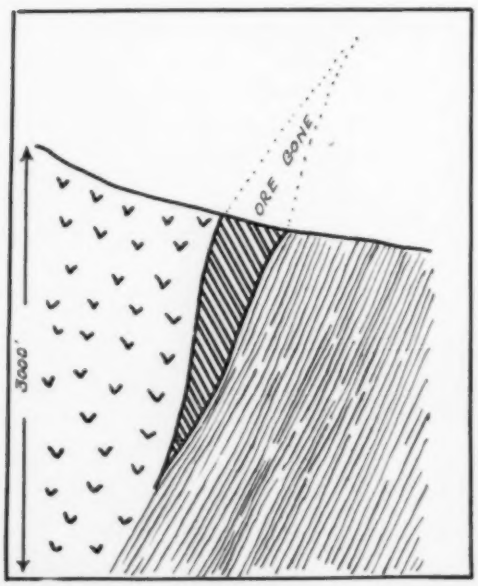


Figure 3.

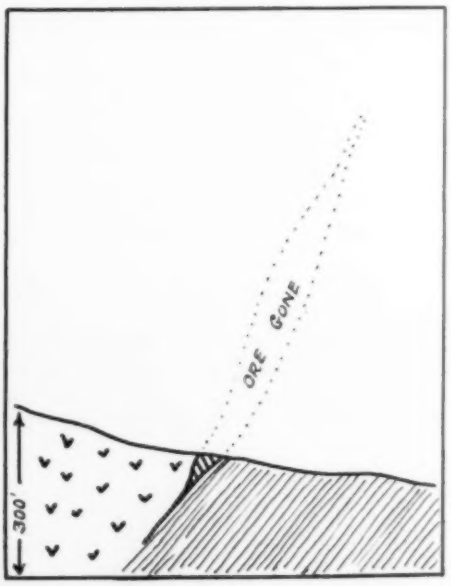


Figure 4.

CROSS SECTION OF ORE BODY

ILLUSTRATING THE SAME ORE BODY AT VARIOUS POSITIONS IN RELATION TO SURFACE, DUE TO EROSION.

raw state, ore-finding methods must be studied more as time goes on, more research must be done along the theories of ore deposition. Much of this work is done to-day, both by the state, by private individuals and by the large mining companies, but all industry will have to realize the need of a future supply and must add its weight to the cause. The U. S. Bureau of Mines, the U. S. Geological Survey, the Canadian Geological Survey and Department of Mines are doing a great work in America. So are many state and provincial departments and surveys—all of which could do much more and better work with larger appropriations. The sums set aside for this work in the very near future must be increased substantially.

Most of our big mines of to-day and, for that matter, the great majority of the small ones, were found as the result of the investigation of a noticeable outcrop. In the older districts, where mining has been carried on for several decades, very few discoveries have been made in recent years; some important finds have occurred in Canada in the until recently little known areas. Are we going to abandon districts that have been important producers for lack of outcrops? It must be remembered that few, if any, ore deposits are formed at or even near the surface; they are, in time, exposed by many and various whims of nature's destructive competitor—erosion. This process of nature is a long and tedious one and is far too slow to be any great aid to man in his search for new mineral reserves after he has exploited those which nature took so long to expose for him.

PACK TRAIN
PEACE RIVER COUNTRY, ALBERTA.

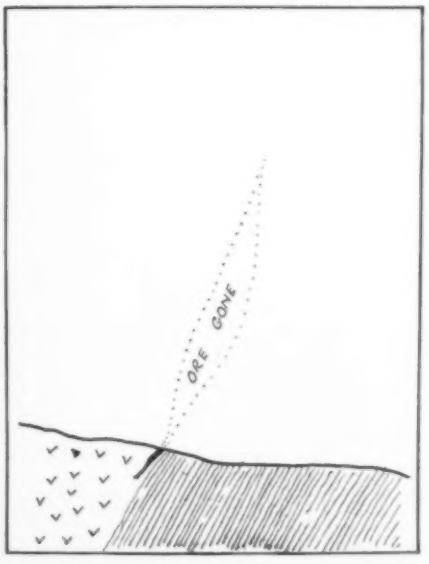


Figure 5.

The several figures will perhaps assist in making the point clear. Fig. 1 depicts section through supposed ore body that does not outcrop—there are no doubt many such instances—truly buried treasure. Such cases as this will be found only after an intensive study and a thorough appreciation of the geology,

which must be based on a very thorough knowledge of the district, its geological literature, past production, etc. Once cases such as Fig. 1 are "sensed," then the various geophysical prospecting methods can be called to the aid of the geologist, for this is his work, not the prospector's. Well-directed diamond drilling should be the next step. Sooner or later finds made roughly along the above lines will be the only discoveries made. There are no "New World" continents with nice noticeable outcrops for man to run to for his future supply of the many necessary minerals; it is evidently a costly process now finding outcrops even in Central Africa.

Fig. 2 depicts an ore body with a poor surface showing, perhaps readily passed up as uninteresting by many. The careful examination by specially trained men, blessed with a real appreciation of physiography (which amounts to what the late Sir Archibald Geikie aptly called "Landscape in History"), should lead to the disclosure of the significance of this type of outcrop.

WINTER IN THE KOOTENAY DISTRICT
BRITISH COLUMBIA.

BIG TIMBER
WEST COAST OF VANCOUVER ISLAND, BRITISH COLUMBIA.

Fig. 3 depicts an ore body with a noticeable surface exposure or perhaps gossan; cases like this are readily discovered by the prospector and quickly developed into a mine and exploited. Such cases are becoming hard to find—some one has stumbled on these before and we have a producing mine or an extinct one in its place.

Fig. 4 depicts a situation which looks encouraging to the uninitiated, the born optimist or the unscrupulous promoter.

Much misdirected capital has been spent on such cases.

Fig. 5 depicts a surface showing that could be, perhaps, mistaken by some for a case like that shown as Fig. 2.

Future prosperity will depend on the skill with which cases 1 and 2 can be found. A small portion of the money spent in the past in an effort to exploit cases like Figs. 4 and 5 would go a long way in the right hands toward the finding of situations similar to Figs. 1 or 2. Cases 4 and 5 must be appreciated and avoided.

In many parts of America the work is greatly complicated, as glacial till, talus slopes, soil and vegetation no doubt mask many deposits in all the various stages or situations.

PTARMIGAN
JUST ABOUT THE BEST DINNER KNOWN.
NORTHERN ALBERTA.

MOUNT STEWART
SKAGIT RANGE, BRITISH COLUMBIA.
PICTURE TAKEN JULY 5TH.

Scouting, as mineral exploration work is usually called, calls for a type of individual not always easily found. The scout must have combined the best of health and an active, robust body with a sound geological and engineering training; he must be capable of facing nature at its best and worst alike. He must quickly adapt himself to any of the various modes of travel, for he will be called upon as a mountaineer, as a river boatman, as a desert traveler, as a dog musher, packer and what not; he should feel at home in an aeroplane. (See snaps by author.) He must be self-reliant, observant and persistent, a born naturalist and a trained scientist. He should have a sound knowledge of mine operating and mining costs; he should be able to drive a good bargain. Admittedly this is a formidable array of pre-

ROCKY MOUNTAIN SHEEP
ALBERTA ROCKIES

requisites. These should serve to make clear the necessity of choosing the right man. Are there going to be enough men of this type to go round? As pointed out in a previous paragraph, not only mining depends on ore finding but an ever-growing industrial civilization depends on the mines for its tremendous metallic needs; this industry is indirectly, but nevertheless very dependent on ore finding.

One nowadays hears a great deal about the reduction of mining costs and the exploitation of lower-grade ore. No doubt costs will be lowered to some extent but there is a limit, and lower-grade ore needs to be in very great quantities if a profitable mining operation is to ensue.

It is common knowledge that more minerals have been used since 1900 than in all previous history. This fact helps one to appreciate the situation and make rough conjectures about the future demand. Can the exploration departments, geologists and prospectors meet that demand? They are going to need help in the form of better knowledge. What is known about ore deposits fills many books, but there are still many

"MAIN STREET," FORT NORMAN, N. W. T.

NEAR THE HEADWATERS OF THE McLEOD RIVER
SOUTH BRANCH OF THE ATHABASKA, ALBERTA.

very important questions relative to ore deposition that remain unanswered. There is an urgent need for cooperation; the various national, provincial and state departments and the universities must get together on the subject of ore finding; the fact that the future demand for minerals will be immense must be kept constantly before us.

Gradually, no doubt, conservation of minerals will be practiced and less will be lost by rust and corrosion as these processes are gradually mastered.

We, in America, must remember that

INDIAN WOMAN AND DOGS PACKED
NEAR FORT NORMAN, N. W. T.

RAFTING ACROSS THE BLUEBERRY RIVER
PEACE RIVER DISTRICT, B. C.

what are now our big producing mines and dividend payers will, in time, become exhausted; mining is not like lumbering—there can be no reforestation; mining is not like agriculture—we can not get our mines back by any system of rotation of crops or by the use of fertilizers. Man's hope must rest on the finding of new ore bodies or the invention of substitutes.

GRAVEL RIVER INDIANS
LOCALLY KNOWN AS THE "MOUNTAIN MEN," IN MOOSE-SKIN BOATS ON THE MACKENZIE RIVER, N. W. T.

DO FISHES FALL FROM THE SKY WITH RAIN?

By Dr. E. W. GUDGER

BIBLIOGRAPHER AND ASSOCIATE IN ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY

BARON HIERONYMUS CARL FRIEDRICH MUNCHAUSEN is by unanimous consent nominated the prince of tellers of "big stories," the first president of the "Ananias Club," but he never told of a rain of fishes. Suspecting that he had such a story, I have carefully gone through a number of editions of his book but have found no rain of fishes. So also John Kendrick Bangs found, but, feeling that Munchausen should have told this and a number of other stories, Bangs has written these up under the subhead "Recent Adventures" and published them in a book —"Mr. Munchausen . . . Embellished with Drawings by Peter Newell."[1]

Now it would seem that Mr. Bangs himself also never heard of a veritable rain of fishes, but had to conjure one up out of his imagination. So he resorts to the clumsy expedient of having his narrator-hero when a boy secure a large quantity of gunpowder and plant this in the bottom of a near-by fishpond. When this was touched off the whole pond was blown high in the air and after some days the contents of the pond, including many fishes, rained down on the astonished people of the neighborhood. Peter Newell drew a figure to illustrate this rain, and this is reproduced herein, since it is one of the three known illustrations of rains of fishes printed in books.

Now the interesting thing is that an imagined rain of fishes is not necessary, for there is a multitude of true accounts of such rains. Having a penchant for the unusual in natural history and particularly for those matters wherein fishes are concerned, for many years I collected and filed away accounts of rains of fishes. Thinking that I had gotten together all the reliable narratives of this phenomenon to be found in scientific books and journals, I compiled this mass of data and in 1921 published it in *Natural History*.[2] There were forty-eight of these accounts ranging in time from *circa* A. D. 300 to 1901, and in space from America (eight accounts), Great Britain (ten accounts), Germany (eight rains), France and Greece (one each), through India (ten), Ceylon (three), Malaysia (two) and the South Seas (one).

The publication of the article aroused much interest in this phenomenon, and letters came in calling my attention to overlooked references and giving personal experience. These, together with certain accounts found by myself in the course of bibliographical work on fishes, were brought together in a second article, "More Rain of Fishes," which appeared in *Annals and Magazine of Natural History*[3] early in 1929. In this paper seven new falls were recorded from the United States, a like number from Europe, from Asia and the East Indies four, Australia seven, South Africa and South America one each. These amount to twenty-six, but I think that three are duplicates and that I have established only twenty-three new falls.

There are thus put on record about seventy-one accounts (more or less well authenticated) of rains of fishes, extending from A. D. 300 until the present—a time span of over 1,600 years—and in

[1] Boston, 1901.

[2] 21: 607–619.

[3] Series 10, vol. 3: 1–26, plate and 2 text-figures.

FIG. 1. A RAIN OF FISHES

PRODUCED BY BLOWING UP THE BOTTOM OF A POND, AS ILLUSTRATED BY PETER NEWELL.
From Bangs, 1901.

space, encircling the whole globe. These accounts in range of time and space make for sure testimony as to the actuality of the occurrence of this phenomenon—there could not have been any collusion among authors. I have personally never been so fortunate as to experience or even witness such a rain, but I can not disregard the evidence recorded by scientific men.

There are two figures, other than Peter Newell's given above, of rains of fishes. I discovered one of these on the very day that my first article went to press. It was of such great interest that I published it in *Natural History* in 1922.[4] It is reproduced from a rare old book (so rare that I know of but four copies in the United States), "Prodigiorum ac Ostentorum Chronicon," published at Basle, Switzerland, in 1557. The author was a learned Alsatian named Conrad Wolffhart, who in accordance with the fashion of his times Latinized and Hellenized his name to Conradus Lycosthenes. This picture, which is reproduced herein as Fig. 2, was drawn to illustrate a downpouring of fishes in Saxony in the third year of the reign of Otho, the sixth emperor of that name, the year being A. D. 689, and is found on page 367 of Lycosthenes' (Mr. Wolfheart's) old book.

[4] 22: 84.

Earlier, however, by two years is that shown herein as Fig. 3. It is taken from that stout old story-teller, Olaus Magnus, Archbishop of Upsala and Primate of Suetia and Gothia, being found on page 726 of the first edition of his book, "Historia de Gentibus Septentrionalibus" (Goths, Swedes and Vandals), published at Rome in 1555. Here it forms the head-piece to a chapter entitled, "Concerning the Fall [or Rain] of Fishes, Frogs, Mice, Worms and Stones [from the Clouds]"—surely an all-inclusive heading. However, no statement is made as to when or where these fishes fell.

The good bishop's book went through many editions and in some of these the illustrations were redrawn and somewhat changed. I have looked through the various editions and versions accessible to me in New York, and in that published at Basle, Switzerland, in 1567, I find a variant drawing of the rain of fishes which is reproduced herein as Fig. 4. In this the fishes are falling in three distinct showers instead of two as in the original illustration.

FIG. 2. A RAIN OF FISHES IN GERMANY IN A. D. 689

From Lycosthenes, 1557.

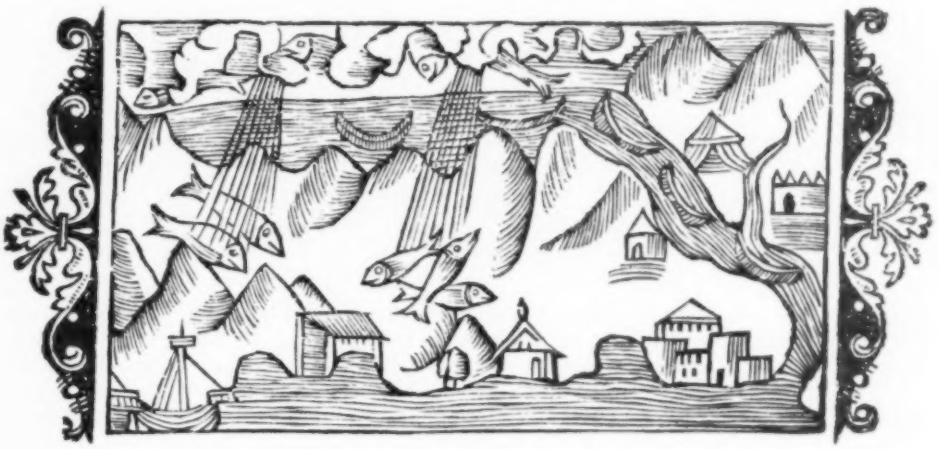


FIG. 3. A DOWNPOUR OF FISHES IN SCANDINAVIA

From Olaus Magnus, 1555.

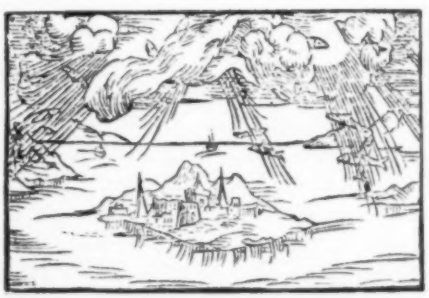


FIG. 4. A VARIANT DRAWING TO ILLUSTRATE THE RAIN OF FISHES IN SCANDINAVIA

From Olaus Magnus, 1567.

Since the publication of my previous articles there have come to me two accounts of falls of fishes which are so well authenticated that it seems worth

FIG. 5. A WATERSPOUT ON JACKFISH LAKE
NEAR NORTH BATTLEFORD, SASKATCHEWAN, CANADA, JULY 20, 1923. PHOTOGRAPH TAKEN AT A DISTANCE OF ABOUT ONE MILE.
Photograph by courtesy of U. S. Weather Bureau.

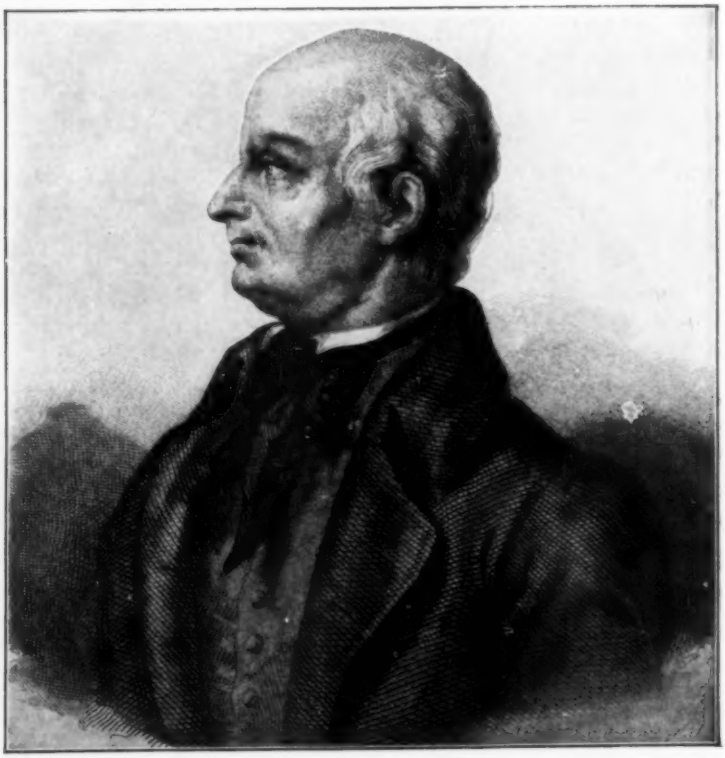
while to put them on record. The first, a personal experience, was related to me by Mr. Richard Hoadley Tingley, of Port Chester, New York, whom I have known personally for a number of years. This fall occurred on May 15, 1900, on the outskirts of Providence, Rhode Island. A severe thunder-storm with a high wind brought a heavy downpour of rain and with it living squirming perch and bull-pouts, from two to four and a half inches long, which fell on yards and streets—covering about a quarter of an acre. Mr. Tingley says that he was out in the storm and was pelted not only with rain-drops but with fish as well. The boys collected these fishes by the pailful and sold them, while a reporter on the Providence *Journal* gathered a bucketful of them and these were displayed in various shop windows on one of the principal business streets of the city.

In July, 1928, I heard of a fall of fishes near Tarboro in my native state of North Carolina. I have spent some time in getting the particulars, and even more effort in getting corroboratory evidence; and I am persuaded that full credence is to be given to the account and to my informants. Here follows the story of this fall of fishes as communicated to me.

On May 18, 1928, a rain of fishes fell on the farm of Mr. S. N. Clark, about

twelves miles east of Tarboro, Edgecombe County, North Carolina. This farm is operated by Mr. W. L. Doughtie, and from him and his wife I have gotten the following details. A heavy downpour of rain came on this day between three and four o'clock in the afternoon. There was very little wind but there were fishes, hundreds of them. These fell on a plot of land that had been planted in cotton a few days before, and which after the storm was covered with water wherein the fishes were found. No one was out in the rain, but immediately after the shower the Doughtie children went out and began wading about in the puddles where they found many litle fishes, some of them alive and swimming. One of the children caught three fishes, brought them to the house and put them in a pan of water. Two of them recovered enough to swim about. Others of the children put some of the fishes in an old unused well, where some of them were seen as late as January, 1929. They were pretty uniform in size, about one and a half to two inches long, about as large as a lead pencil and dark in color. No means were at hand for preserving any of them, hence they can not be identified. Mr. Doughtie estimates that there were several hundreds of these little fishes scattered over two or three acres of ground. This spot is some three quarters of a mile from the nearest water course, which is not known to contain any numbers of fishes.

Now for the explanation of these and all other rains of fishes. There is but one. High winds, particularly whirlwinds, pick up water, fishes and all, and carry them inland where, when the velocity of the air and clouds becomes relatively lowered, the fishes fall to earth. Can any one doubt that a waterspout such as that shown in Fig. 5 could pick up and carry off fishes? In appearance it is just such a one as once passed near me at the Marquesas Atoll about twenty miles west of Key West, Florida. This particular spout on Jackfish Lake, near North Battleford, Saskatchewan, Canada, first appeared from a wheat-field and traveled about fourteen miles down the lake until it was stopped by a small island. Had it lifted from the water and gone inland and then burst, it would have produced a prodigious fall of rain, and had there been any fishes in the lake under its basal end, these would certainly have been sucked up in the whirl, carried inland and later rained down. No reader of this article who has experienced or even seen the prodigious effects and carrying power of a land tornado can have any doubt of the ability of a waterspout, a water tornado, to bring about a "Rain of Fishes."



LAZZARO SPALLANZANI

LAZZARO SPALLANZANI

(1729–1799)

By Professor A. ELIZABETH ADAMS

ZOOLOGY DEPARTMENT, MOUNT HOLYOKE COLLEGE

ALTHOUGH Spallanzani worked nearly two hundred years ago—his birth occurred on January 12, 1729—his findings are still quoted, his methods commended and, especially in experimental science, both the variety and nicety of his experiments and the accuracy of his observations sanction his right to be considered one of the founders of experimental zoology. "The genius of Spallanzani touched and adorned so many things that it is impossible to avoid coming constantly upon his work," writes Cummings,[1] and this statement finds ample proof whether the subject be of zoological import (digestion, respiration, reproduction, spontaneous generation, regeneration and the like), meteorology, the founding of museums of natural history, or travels in southern Europe.

Spallanzani's training[2] was as varied as his interests. After spending his childhood at Scandiano, where he was born, he began his more advanced study at the Jesuit College at Reggio di Modena in 1744 where his principal subjects were law and theology, probably due to the influence of his father who was an advocate. But his later sojourn at the University of Bologna tended to give his natural scientific inclinations free rein, and in this he appears to have been aided and abetted by his cousin, the famous woman scientist, Laura Bassi, and by Vallisneri, professor of natural history at Padua and a native of Scandiano. In 1754 at the age of twenty-five, his appointment as professor of logic, metaphysics and Greek[3] at the college at Reggio is indicative of his versatility, while his first paper, "De lapidibus ab aqua resilientibus dissertatio," is the straw which shows that the wind was blowing in a scientific direction. In 1760, by accepting the chair of physics[4] (some authorities say it was natural history[5]) at Modena, he had the opportunity to give himself more fully to scientific work, and his paper on "The Origin of Springs" was followed by others of a zoological nature on spontaneous generation (Saggio di Osserv. microscop. concern. il systema di Needham e Buffon, 1765), on the circulation (Dell' azione del cuore ne' vasi sanguini; nuovo osservazioni, 1768) and on reproduction (Prodromo di un opera da im primersi sopra le riproduzioni animali, 1768). Sometime in this period he took priest's orders, although it is thought that he was never very active in this profession.

[1] B. Cummings, 1916. "Spallanzani." Sci. Prog. in XXth Cent. Vol. 11, p. 236.

[2] Data for the account of Spallanzani's life are taken from the following sources: Cummings, *loc. cit.;* A. Massaglia, 1925. "Lazzaro Spallanzani." Med. Life. Vol. 32, pp. 149–169; W. Stirling, 1902. "Some Apostles of Physiology." London. pp. 60–64; Encyclopaedia Britannica, 1911. 11th ed. *s. v.* Spallanzani.

[3] Subjects are variously given by different authorities, *e.g.*, Encycl. Brit., logic, metaphysics and Greek; Cummings, logic and geometry; Massaglia, mathematics and physics at University of Reggio Emilia, and Greek and French at the college; Stirling, logic, mathematics and Greek.

[4] At this time he is said to have received calls from Coimbra, St. Petersburg, Parma and Modena; Massaglia, *loc. cit.*, p. 33.

[5] Stirling, *loc. cit.*, p. 61; M. Foster, 1901. "Lectures on the History of Physiology." Cambridge. p. 212.

In 1769 he was called to the chair of natural history in the University of Pavia, and initiated his labors with a defense of the preformation theory. Here he continued his studies on the circulation (De' fenomeni della circolazione osservata nel giro universale de' vasi; de' fenomeni della circolazione languente; de' moti del sangue independent; dall' azione del cuore, e del pulsar delle arterie. Dissertazioni quattro, 1773) and published tracts on spontaneous generation, on regeneration, on mating habits of animals and many other matters (Opuscoli di fisica animale e vegetabile, aggiuntevi alcune lettere relative ad essi opuscoli dal Signor Bonnet e da altri scritte all' autore, 1776). One of the outstanding events of his connection with Pavia was the founding of the Natural History Museum, which he built up largely through his own zeal and ability as a collector. As he later claimed, "It had been born under his hands, it had grown under his direction, and owed its prosperity to his correspondence, activity and travels."[6]

The year 1785 saw him receive an invitation to Padua which he did not accept but used as a tool for securing a larger salary at Pavia and for getting permission and funds for a journey to Turkey, where he was received by the sultan. During his absence from Pavia some of his colleagues began checking up on the specimens in the museum and finding some catalogued but absent from the shelves and being spurred on by jealousy of his popularity in the university and with royalty, they investigated a private museum which he maintained in Scandiano. There they found certain objects labeled with tags of the museum at Pavia and accused him of filching these from the museum. He stood trial on his return from Turkey and was able to clear himself and rout his enemies, some of whom suffered decidedly from having tampered with his affairs.

The later years of his life were spent largely in teaching, investigating and traveling, in publishing other editions of his work on the "Natural History of Animals and Vegetables" and in writing a six-volume account of his journeys (Viaggi alle due Sicile e in alcune parti dell' Apennino dell' abate L. Spallanzani, 1792–1797). His death from apoplexy occurred in Pavia in 1799.

Of what sort was this man, the bare outline of whose life has been sketched above? And why have his labors stood the test of time? That Spallanzani possessed a vivid personality and an abundance of self-assurance seems evident from the impression he made on contemporaries and from all accounts of his contacts with his fellow men. As Cummings pictures him we see a magnetic and assertive man who was bent on having his say in all matters that concerned him.

> Greedy, ambitious, arrogant, and at times violent, Spallanzani was a bull-moose type of man who charged through life with his head down. There were many obstacles to his success, but he brushed them aside; he had many detractors, but he pinned them down. To his opponents in biological controversy he never expressed any flabby desire to agree to differ. They were attacked with acerbity, and whether right or wrong he emerged triumphant. False modesty was not one of the Abbé's faults. When as a young man conscious of his own genius, he ventured upon a criticism of the illustrious Buffon, he did so with a sardonic expression of his own incompetence. He never showed the smallest inclination to mislead his contemporaries into giving him less than his deserts. He set out to be second to none—not even in salary—and he succeeded and was proud of it.[7]

As a critic Spallanzani could be scathing. Nowhere is this more apparent than in his evaluation of Buffon's work on spontaneous generation in the light of his own accurate experimental evi-

[6] Cummings, *loc. cit.*, p. 242.

[7] Cummings, *loc. cit.*, p. 236.

dence. "M. de Buffon's theory is thus completely destroyed. Such is too often the fate of the hypotheses of ardent and fanciful philosophers, first invented and then sought for in nature."[8] And his friend Bonnet even thinks it worth while to advise him of the proper character of scientific criticism. "The examination of Mr. Needham's hypothesis on generation will require a severe criticism from you; but you will make it in polite, moderate, and friendly terms. You are acquainted with the character of this learned naturalist, and cherish the same esteem for him as I do myself."[9]

Together with fanciful hypotheses, garnished accounts of facts well able to stand alone receive a merited rebuke.

> Mr. Brydone, indeed, through his whole journey to Etna has sufficiently shown his attention to the marvellous, and, when that has failed him, has had recourse to the aid of his playful fancy to furnish him with extravagant though ingenious, inventions of the ridiculous kind. . . . But would it not have been more commendable to have furnished his readers with real information, instead of filling so many pages with these trivial and insipid pleasantries? In fact, after having read his five letters on Etna, what idea do they enable us to form of the nature of this mountain?[10]

Then perhaps feeling that he has failed to give proper credit, he adds:

> I do not mean, by what I have said, indiscriminately to condemn the whole work of Mr. Brydone. His "Tour" [through Sicily] frequently contains facts and observations well-deserving attention. It is elegantly written, and the author was well acquainted with the secret of exciting our curiosity, and rendering his narrative interesting; though frequently, with that kind of interest which seems more suitable to romance than to authentic history.[10]

[8] L. Spallanzani, "Tracts on the Natural History of Animals and Vegetables." (Transl. fr. orig. Ital. by J. G. Dalyell, Esq. [2nd ed.] 2 vol. Edinburgh. 1803); Vol. 2, p. 22.

[9] Dalyell, Transl. 1803. Letter from Bonnet to Spallanzani, included in Transl. of Tracts, etc., Vol. I. p. 158.

[10] L. Spallanzani, "Travels in the Two Sicilies, and Some Parts of the Apennines." (Transl. from orig. Ital. of Spallanzani. 4 vol. London 1798); Vol. 1, footnote, pp. 203–204.

Perhaps one of the most attractive glimpses of Spallanzani lies in his own appreciation of his friend Bonnet, the man who with Trembley, Réaumur and Spallanzani was responsible for much of the experimental zoology of the eighteenth century. After describing Bonnet's urgent request to other naturalists to take up and further the experiments on regeneration in earthworms and in higher forms, he says:

> Is there any one who would not wish to obey such an invitation, coming from a man universally allowed to be one of the foremost naturalists of the age? But how much more powerfully must I have been influenced by it, who, besides these invitations in common with other philosophers, was frequently and particularly solicited by him on this account, and who am also connected with him by the strictest friendship, which constitutes one of the chief blessings of my life.[11]

That Bonnet reciprocated that friendship and respected Spallanzani's work, even to crediting him with "discovering more truths in five or six years than all the academies in half a century,"[12] is evident again and again in the former's letters:

> I can not terminate this long epistle, my worthy correspondent, without renewing the testimony of the great esteem, and sincere attachment, which have been borne towards you by the Palingenisist.[13] . . . Fear not that M. de Buffon's authority will in the least invalidate the truth of your discoveries on seminal vermiculi. You have proved yourself an excellent observer, and acquired the right of being believed. You have cherished no theory, but are satisfied with interrogating nature, and giving the public a faithful account of her responses. Philosophers will always listen to you; and they will esteem your observations so much the more certain that you prove yourself to possess the art of observation.[14]

It is not surprising to find that Spallanzani was successful as a teacher. He

[11] Spallanzani, 1769. "An Essay on Animal Reproduction." (Transl. from Ital. by M. Maty. London.) Introd., pp. 3, 4.

[12] Cummings, *loc. cit.*, p. 239.

[13] Dalyell, *loc. cit.*, letter from Bonnet to Spallanzani. p. 266.

[14] *ib.*, p. 326.

not only had an excellent background of general and of scientific knowledge, but was always eager to try something new, to demonstrate his experiments before his students, to give them the benefit of his philosophical meditations. He could not be content with repeating the minutiae of dry detail which appeared to be the meat of those systematists whom he sarcastically termed "nomenclature naturalists," and only consented to give up his cherished desire to have students use his translation of Bonnet's "La Contemplation de la Nature" for their reference book and to give proper attention to the subject of nomenclature when he was promised an increase in salary. Even then it is said that he managed to intersperse his experiments in the midst of systematics. In addition, he possessed great ability as a lecturer. "Une éloquence simple et vive animait ses discours; la pureté et l'élégance de son élocution seduisaient ceux qui l'entendaient."[15] It is probable that his unwillingness to conform wholly to conventional standards, his enthusiasm as a teacher and his vigorous scholarship all contributed to that popularity which led to his election by the students as rector of the university in 1778, and to his overwhelming reception by them on his return from Turkey and Vienna in 1786.

The second question, why Spallanzani's labors have stood the test of time, may perhaps find a partial answer in the fundamental nature of the questions which he investigated, in the methods he used and in the way he recorded his observations. As already evident in his criticism of Mr. Brydone's fanciful writings, he had no patience with such a style, especially when truth itself was so much more wonderful than fancy. His ideal for scientific papers is given in the introduction to his "Prodromo di un opera sopra le riproduzioni animali," that work which was to have been merely the outline of a much larger work on the same subject.

> To lay down facts with the faithfulness of a true historian of nature; to pass, as much as possible, from the most simple to the most complicated; to bring them together, to analyze and compare them both with themselves and with the discoveries of other authors; to deduce with impartiality the immediate consequences, either favorable or contrary to the explanations given of those extraordinary phenomena; to shew how far the limits of animal physiology are extended by, and what utility and advantage may be derived from observations of this kind will be the principal design of this work. . . .
>
> As several of the results of my experiments will appear singular, I shall make it my business to describe them with precision, to mention the precautions and means I have used in making these observations, the temperature of the air, and the situation proper for the animals, together with the food I gave them; and in short, to disclose all the circumstances which may contribute to the understanding, and establishing of the facts, so, that the lovers of natural history, on repeating my experiments, may, if they please, confirm and extend them still farther. . . .
>
> I have thought a sufficient number of figures would be of the greatest importance to the subject: if they are generally ornaments in books of natural history, they may be said to be the life and spirit of mine.[16]

After reading these quotations it is self-evident why Minot one hundred and fifty years later in writing of the "Method of Science," particularly as it concerns scientific papers, says that "Spallanzani established the modern standard."[17]

Nor when we look over the contents of this work, whose introduction has been quoted in part, and find studies of regeneration in earthworms, in aquatic boatworms, of the tadpole's tail, of tails, legs and jaws in aquatic salamanders, of legs of frogs and young toads, of the head and other parts of the land snail,

[15] Cummings, *loc. cit.*, p. 239. Quoted from Sénébier.

[16] Spallanzani, "Essay," transl. by Maty, *loc. cit.*, pp. 4, 5, 6.

[17] C. S. Minot, 1911. "The Method of Science." *Sci.* N. S. vol. 33, p. 123.

of horns in the slug, all examined from many points of view (*e.g.*, the rate of regeneration, the order of regeneration, the effect of amount removed and age on regeneration, the variation in the capacity of species to regenerate, the microscopic appearance of the regenerating parts, does Garrison's evaluation of the work seem extravagant: "These experiments were not taken up again until the end of the nineteenth century, but they contain all the essentials of the modern work of Roux, Driesch, Morgan, Loeb, and others."[18]

One example of Spallanzani's method of analysis is worth consideration because of the grasp of detail and the thoughtful planning of experiments which it reveals. After noting the necessity of knowing the conditions of the animal before and at the time of the operation, he sets a series of questions as to the results of cutting of earthworms transversely into four, five, six or more parts.

> With regard to the consequences of the section, I examined 1. What new order and disposition the dividing fibers and vessels acquire? 2. What time it takes up after the section, before a new production begins to make its appearance? 3. What is the form and structure of the reproductions; and in consequence, how far they agree or disagree with the first parts? 4. Whether the circulation in the great artery, formed by the reproduction, is analogous to that of the whole worm: namely from tail to head? 5. In what manner are the great artery, the intestinal tube, and the other parts existing in the old animal, united to the new parts? 6. Whether, *caeteris paribus*, the reproduction grows in proportion to the length of time, and the warmth of the weather? 7. Whether all the parts, similar or dissimilar, which existed in the old, are also found in the new, worm? 8. Whether the reproduction, after sections parallel to the plane of the rings, keeps the longitudinal direction of the worm? 9. Whether this direction varies with that of the plane of the section? 10. What interval of time is required before the new-produced parts are able perfectly to perform the functions of those that were cut off? 11. Whether on the lengthening of the reproduction, the trunk increases likewise? 12. Whether after a certain time the reproduction becomes equal to the old part, both in bulk and length?[19]

For studies other than those on regeneration, his enthusiastic persistence succeeded when the efforts of others went unrewarded, and in 1771 he was able to announce the discovery of the circulation of the blood in capillaries in warm-blooded animals. This was exactly one hundred and ten years after Malpighi had demonstrated its occurrence in cold-blooded forms, and after Malpighi himself, Leeuwenhoek, Cooper and Haller had all failed in their attempts to demonstrate the phenomenon in warm-blooded types. As Luciani quotes him:

> Long have I been burning with curiosity to discover the circulation in warm-blooded animals, and to grasp it as completely as in the case of the cold-blooded; hence these vessels ("umbilicals of the chick") attracted my observation more than any others, and invited my consideration, because they belonged to the said animals. Since the room in which I found myself was insufficiently lighted, and I was determined at all costs to satisfy my curiosity, I decided to examine the egg in the open, under direct sunlight. After fixing it in the apparatus of Lyonet ("a small microscope used by Spallanzani") I turned the lens upon it, and, notwithstanding the strong light that surrounded me, was enabled by focussing my eyes, to see plainly how the blood flowed in the entire circuit of the arterial and venous umbilical vessels. Thrilled with this unexpected joy, I felt that I, too, might exclaim, "I have found it! I have found it!" I made this discovery in May 1771, and employed myself in the summer vacation of that year with its development.[20]

Although this discovery and the explanation of the phenomenon of the arterial pulse are perhaps the most interesting that he made in the field of circulation, they are only two of many lines worked upon, such as the elasticity

[18] F. H. Garrison, 1921. "History of Medicine," 3rd ed. W. B. Saunders Co. p. 330.

[19] Spallanzani, "Essay," transl. by Maty, *loc. cit.*, p. 14.

[20] L. Luciani, 1911. "Human Physiology." (Transl.) Macmillan. Vol. 1, pp. 172–173.

of red blood corpuscles, the functions of the heart and the rate of flow of blood through the blood vessels.

Among Spallanzani's investigations which are most often met in the literature are those on digestion[21] and with good reason. These followed the classic experiments of Réaumur and were to some extent repetitions of Réaumur's on digestion in the kite and other animals. The thoroughness with which Spallanzani carried out his studies not only on types of vertebrates from fish through mammals, but even on himself, is indicative both of his method and his analytical approach to the subject. He demonstrated the contractions of the stomach when distended with food, by making a guinea-fowl swallow hazelnuts and then watching the behavior of the stomach as it became filled by the nuts. He studied the effects of the stomach juices on bits of food contained in small metal or wooden tubes or in linen bags, securing them again for examination either by pulling them from the stomach by strings attached to them, in the feces, or by opening the stomach after the objects had been retained a certain amount of time. He likewise procured samples of gastric juice by recovering sponges from the stomach of various animals or by making himself vomit on an empty stomach and used these juices to carry on experiments in digestion outside the body, carefully regulating the temperature conditions and using bits of food in water as controls. By these and many other tests he was able to demonstrate that the gastric juice possessed distinct solvent properties and prevented putrefaction. It is curious that he missed the acid nature of the gastric juice, for some of his experiments seem to demonstrate this so adequately.

[21] Foster, *loc. cit.*, pp. 212–219; Luciani, 1913, *loc. cit.*, Vol. 2, pp. 153, 179, 185, 189; Stirling, *loc. cit.*, pp. 61–62; Spallanzani, "Dissertations Relative to the Natural History of Animals and Vegetables." (Transl. by Thomas Beddoes. 2 Vol.) 1789.

Spallanzani likewise became much interested in the subject of respiration[22] both in warm- and cold-blooded animals, in vertebrates and invertebrates. These studies were mainly published in 1803 after his death by his friend Sénébier, but possibly failed to receive as much credit as others of his works because he was not alive to defend them. His experiments range over a large field: confining animals in stagnant air and noting the effects; studies on hibernating animals especially when subjected to an excess of carbon dioxide; placing animals with or without lungs, or parts of animals, *e.g.*, ovaries, stomach, liver, intestine, in atmospheric air and observing how oxygen is taken up and carbon dioxide given off by these animals or by their excised tissues. As Stirling sums it up:

> Here, was a mighty stride forward: oxydation does not take place in the lungs, nor, indeed, in the blood. It is the tissues that respire, *i.e.*, consume oxygen and give off carbonic acid. Spallanzani had studied profoundly what we now call "internal respiration." Secondly, it is not the oxygen taken in on which the tissues live, and give out carbonic acid, for snails and "worms" give off this gas in an atmosphere of pure azote or hydrogen.[22]

His observations on the respiration of excised tissue only lack quantitative details to make them wholly modern in sound.

The field of reproduction in the animal kingdom claimed much of Spallanzani's attention and his studies included many on Amphibia—their mating habits, the process of fertilization and the development of the embryo—as well as on higher forms. In addition to watching the normal reactions, he investigated experimentally certain features of sexual behavior, especially the clasp reflex in Anura. Luciani quotes from the Genevan edition of 1876 by Sénébier the description of certain experiments.

[22] Foster, *loc. cit.*, p. 253; Luciani, *loc. cit.*, Vol. 1, p. 375; Stirling, *loc. cit.*, p. 72.

Finding two toads in copulation I separated them forcibly; I cut off the thighs of the male and put it down near the female; it then embraced her anew. I cut off the hands of the male toad and placed it near a female; as we know, the males use their hands in copulation; it seized the female with its bleeding stumps and did not release her till all the ova were fertilized. On cutting off the head of a male frog in the act of copulation, it did not let go of the female with its arms and hands; it bathed the ova for an hour and three quarters with its seminal fluid, and nearly all of them developed into tadpoles.[23]

In his contention that preformation occurred in the amphibian and other eggs, Spallanzani was led astray. In no uncertain terms he claims that the embryo exists in the egg, simultaneously eliminating the ideas of the "spermists" and aligning himself against any active rôle of the sperm cells. In that part of the "Essay on Animal Reproduction" called "On the Existence of the Tadpoles in Eggs before Fecundation," he compares the fecundated and unfecundated egg and failing to find any real difference between the two, decides that the embryo must exist in the egg as it passes down the oviduct before fecundation. After a description of cleavage and embryo formation, he writes:

Such are the phenomena, which gradually make their appearance in the fecundated eggs. Hence it must be obvious, that these are not properly, as was imagined before, the eggs from which the tadpole grows, but rather the tadpoles concentrated and coiled up in themselves . . . and . . . the tadpoles exist before fecundation and require only the fecundating liquid of the male to unfold themselves.[24]

As to the rôle which the seminal fluid really plays, he continues:

Before fecundation, the small heart of the germ wants force sufficient to overcome by its impulse the resistance of the solids. This force it receives from the fecundating liquor which stimulates, gently irritates, and obliges the heart to propel with greater power the fluids, through the smallest canals. The same liquid afterwards becomes nutritious, bringing about the development of the germ, which supplies nourishment.[25]

But he feels that these ideas do not fit the case in the development of the tadpole and becomes hopelessly involved in an explanation which really merits a rebuke as severe as those he administered to others.

Tadpoles, or if you please, the eggs of tadpoles, unfold themselves considerably before fecundation. One of these when in the uterus, is at least three times bigger than the same, while still attached to the ovaries. They are animals therefore, the germs of which are not disclosed at first by the spermatic fluid, but by the juices of the mother, and since this unfolding or increase of bulk is performed by nutrition, which must imply a circulation of fluids, and that such a circulation can not be carried on without the action of the heart, we are obliged to infer that these maternal juices are themselves that kind of stimulus which the seminal liquor is supposed to be in birds. Consequently the heart in the germ of the tadpole must beat sufficiently to produce a circulation of fluids, without an insuperable impediment from the solids.[25]

In the paragraphs which follow, he appears disturbed at the fact that these "tadpoles" perish unless fecundated and yet he can not quite assign any rôle to the seminal fluid. He finally takes refuge in a series of interesting but somewhat irrelevant questions.

Misinterpretations appear to run through others of his studies on fertilization. Although successful in artificially inseminating not only amphibian forms (terrestrial frog, water-newt, fetid terrestrial toad, tree-frog, green aquatic frog) but also a dog,[26] he persists in asserting that sperm cells are not the fertilizing elements proper, and even

[23] Luciani, 1917, *loc. cit.*, Vol. 4, pp. 78–79.

[24] Spallanzani, "Essay," transl. by Maty, *loc. cit.*, p. 42.

[25] *ib.*, pp. 45–46.

[26] F. H. Marshall, 1922. "The Physiology of Reproduction." 2nd ed. Longmans, Green & Co. pp. 174–175. Quotation of a contemporary English translation of Spallanzani's experiment.

after filtering seminal fluid, he claims that the filtrate alone is potent in fecundation. Why he should have interpreted his data in this way is scarcely to be understood both in view of experiments which demonstrated the reverse and his usually clear logic. As Lillie points out, Spallanzani deserves the credit for the pioneer experiments on artificial parthenogenesis because he tried "to start development of eggs, by electricity, by the action of extracts of all the various organs, by vinegar, dilute alcohol, lemon juice, and other substances," although with no success.[27] These experiments were all undertaken primarily to see whether other fluids besides the seminal one might accelerate the vital process, which he believed to be the rôle of the latter.

One problem which interested Spallanzani almost continuously in his career was that of spontaneous generation.[28] His chief opponents in this field were Buffon with his "organic molecules" and Needham with his "vegetative power." Although in reading Spallanzani's account of his work it is evident that there were some gaps in his experiments, it is certain that he was able to demonstrate the absence of animalcula in liquids contained in hermetically sealed flasks and sufficiently boiled, and Murray's claim that "Spallanzani had anticipated one of the most renowned of the experiments of Pasteur with results that would have satisfied the French investigator,"[29] seems fully justified.

Among less well-known experiments which he carried on are those on bats. In an attempt to discover how these animals avoid objects as they fly, he blinded the animal sometimes by burning the eyes with a red hot wire and sometimes by removing the organs altogether, and even filling up the orbital cavity with wax. Notwithstanding these mutilations, the little creatures were able to fly as well as before, avoid the walls, and the strings suspended in the path of their flight. These and other experiments led him to the conclusion that bats find their way in the dark by means of some special sense situated in an unknown organ on the head. It is now generally accepted that this astonishing faculty in bats of directing their flight is due to an exceptional development of sense of touch, especially in the wing membrane.[30]

Studies in other subjects, such as physics, chemistry and geology, consumed much of his time in the laboratory and in the field. He appeared to be equally at home in these branches of science, and in the travels which he undertook to add to the collections in the museum at Pavia, he was often forced to be both "naturalist and chemist." He revealed many times his ingenuity for conducting experiments when far from his laboratory, perhaps nowhere better portrayed than in his examination of the phosphorescence of certain medusae which he collected in the Straits of Messina. Besides studying the anatomy and physiology of these curious forms, he dried them, squeezed them into various liquids (water, urine, milk) and did many other things to test their capacity to give off light.[31]

A single medusa of a moderate size, being pressed and shaken in two ounces of this milk, rendered it so luminous that I could read the writing of a letter at three feet distance. The duration of this phosphorescence was likewise greater than that of the water. After eleven hours from the time I first put the medusa into it, it still retained some light; and when that

[27] F. R. Lillie, 1919. "Problems of Fertilization." Chicago. pp. 6–9.

[28] F. H. Garrison, *loc. cit.*, p. 329; Spallanzani, "Tracts," transl. by Dalyell, *loc. cit.*, Vol. 1, p. 13.

[29] R. H. Murray, 1925. "Science and Scientists in the Nineteenth Century." London. p. 236.

[30] Cummings, *loc. cit.*, p. 240.

[31] It is interesting to note that Harvey (1920, "The Nature of Animal Light," Lippincott, p. 85) speaks of Spallanzani's experiments on phosphorescence as being of "great importance in understanding the nature of animal light."

ceased, agitation restored it, as did warmth, when agitation alone became ineffectual.[32]

While his "Travels" primarily record natural history observations in the widest sense, *e.g.*, erosion, rock formation, volcanic fires, lava flow, swordfish and coral fisheries, varying species of Ampnibia and birds, the customs of people, and dozens of other items, they also give us delightful and picturesque glimpses of his adaptability to the exigencies of traveling.

> The ascent up the steep and craggy cone of Etna, though not more than a mile in a direct line, cost me, as I have already said, three hours of laborious and fatiguing exertion. It seems scarcely necessary to say that the descent employed me less time, but the difference greatly exceeded my expectation. I found that to effect this descent nothing more was required, but to fix my feet firmly on some large pieces of scoriae, and balance my body, since that piece, from almost the smallest impulse I could give it, would slide swiftly down the descent, and convey me to a considerable distance, till stopped by the accumulation of the lesser pieces of scoriae which it drove before it; when I had only to select another large piece, on which I glided down as before; only taking care, with the staff I held in my hand, to turn aside the pieces of scoriae which followed me in my descent, that they might not strike against and wound my legs. In this manner, in a few minutes, I arrived at the bottom of that declivity.[33]

An equally interesting insight into the fundamental humanness of the man is the reward of a perusal of these volumes. He was poignantly aware of the people with whom he came in contact. He notes the tragedy in the lives of the folk who live near Etna and must go nearly ten miles for water. He responds with a ready gift to the child who broke his jug and had no money to buy another. He expresses his thanks to the priest who helped him when he was nearly shipwrecked, "a man towards whom I shall feel the warmest sensations of gratitude while life shall remain."[34] He records his genuine appreciation of the gift of some pieces of rare white coral from another priest.

Tucked away in the "Travels" is the following revealing comment by its author. "The powers of the human mind are so limited that it can never entirely exhaust the subject it investigates."[35] However, this consciousness of human limitations did not keep Spallanzani from delving into many fields of knowledge, and from making valuable contributions on many subjects. In fact, his versatility is both overwhelming and refreshing in these days of specialization, and what is perhaps most amazing in his researches is that he made relatively few mistakes in his manifold attempts to find out nature's secrets.

[32] Spallanzani, "Travels," transl., *loc. cit.*, Vol. 4, pp. 238–240.

[33] *ib.*, Vol. 1, pp. 287–288.

[34] *ib.*, Vol. 3, p. 130.

[35] *ib.*, Introd., p. viii.

PALEO-MALTHUSIANISM

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EARLIEST ideas upon the subject of population, gathered from the writings of ancient peoples, appear to be nothing more than articulated instincts, born of the struggle for existence. These ideas sprang from the innate feeling that one must prevail or succumb, and that one's kind must prevail or finally be obliterated. What Stangeland[1] calls "a religious veneration of procreative powers" expresses the general trend of early thought, though there is an occasional instance of what appears to be a contrary trend—where a restricted population seems to have been desired. On closer scrutiny, however, these cases frequently disclose another purpose.

The instinct to prevail, or—when it becomes rationalized—a war policy, seems to have been the central motive in all early population theories. Even during classic times, in Athens, in Sparta and elsewhere in the Hellenic civilization, what appears to be an indubitable restriction policy proves upon better understanding to be an early essay at the art and science of eugenics—looking mainly toward the creation of more effective fighting men and more efficient public servants.

Most of the Greek city states regulated minutely the lives of their citizens.[2] The regulation of marriage and celibacy was expressly prescribed. Marriage was not entirely a religious institution, nor was it held to be solely a personal concern; it was a semi-public institution, looking toward the production of sound citizens.[3]

Here, as in most matters, the Spartans were particularly thorough. This virile city state, so frequently engaged in wars that decimated her fighting men, put into effect every possible provision for the production of first-rate warriors. Marriage was compulsory. Bachelorhood was condemned by law and by public opinion. In pugnacious little Sparta, where so few escaped the sword long enough to attain to a great total of years, youth was not required to pay to elderly bachelors the respect customarily given to old age. Marriage was the honorable estate; celibacy was disgraceful. Here we find expressed, both in law and practice, the old instinct to persist—if not in person, then in progeny—but with characteristic thoroughness these Greeks added something, the eugenic idea. Not only did Sparta decree more children, but better children. Infanticide was practiced but more in consideration of quality than of numbers.[4]

The Athenian policy was more liberal. There were laws against bachelorhood, but in peace times they were evaded; in fact, late marriages were generally advocated. Here is probably the first palpable evidence of a new population policy—an expressed desire to restrict the number who share in the limited good things of life. Further evidence is not wanting. The Athenians, by encouraging emigration and by permitting the practice of infanticide, expressly recognized the constant fact of overpopulation. We find then in Athens a middle policy, marking a transition from the program of unlimited expansion—the program of poor and war-like states—to the out-and-out restrictive policy of

[1] C. E. Stangeland, "Pre-Malthusian Doctrine of Population," p. 16.

[2] H. Blumner, "The Home Life of the Ancient Greeks," p. 177.
Rostovtzeff, "A History of the Ancient World."

[3] G. W. Botsford, "Hellenic History," p. 409.

[4] *Cf.* E. B. Reuter, "Population Problems," pp. 40–42.

rich, populous and peaceable states—a bridge between ancient and more modern ideas on population.

But in defining Athenian population policy, the practice of infanticide must not be taken too seriously. It was first of all a eugenic measure, and secondly, a means of personal convenience. It must, however, be taken, in part, as indubitable evidence of a restrictive population policy, for we find among primitive peoples that, wherever originally easy living conditions brought forth a swarming population, infanticide was practiced. In Polynesia it was at one time quite general. In Hawaii children after the third or fourth were strangled or buried alive. Tahitian fathers had the right of doing away with the newly born. In the Society Islands infanticide was imposed upon women by oath.[5]

Plato, in his philosophy, provided for a careful regulation of population—to preserve social equilibrium. His state was to consist of a limited number of citizens (5,040). If the number began to decrease, prizes might be offered to encourage the growth of population; if there was excess, colonies could be developed.

Aristotle's program was almost exclusively negative and restrictive. The number of children was to be strictly regulated. Exposure was to be the fate of ill-formed or superfluous children. Pregnant women who had already borne the legal number of children were to be relieved of their burden.

The Romans absorbed Athenian ideas in the field of population as they did in nearly every other field of human interest; Rome added nowhere to Greek ideas—except in agriculture and in making war. The Greek culture and people spread and conquered, but conquest was not a principal aim. Students of Greek antiquity maintain that perfection was the pole-star of the Greek culture. There is no mistaking, however, the Roman philosophy and program of conquest and expansion.

The population policy of the Roman Empire was exactly what a policy of military conquest invariably demands: an unlimited expansion of population and all possible encouragement for the production of new citizens and worthy fighting men. As early as A. D. 10 the *Lex Papia et Poppoea* was enacted—mainly through the efforts of two bachelor consuls—for the purpose of encouraging marriage and legitimate fertility in Rome.[6] Here, as in Greece, marriage was a semi-public institution—with the primary purpose of producing worthy citizens. Strangely enough, the families of the upper classes were not very large, and we can conclude that patricians who preached one policy in the forum practiced its opposite in private. Official policy, however, was clear: marriage was encouraged by rewards and amenities; bachelors were taxed. But as time went on these regulations seem to have had little effect. The burden of large families began to bore the later and more urbane citizenry of Rome.[7]

Romans then were latitudinarian in their views on marriage. The austerity and the socialistic ideas of the Greeks were wholly wanting—or they were represented by a few legislative gestures, more scoffed at than observed. Ineffectual legislative jack-o'-lanterns for bachelors were hung out by the later emperors. Julius forbade unmarried women of more than twenty-three years jewelry and other luxuries, and he rewarded those who bore many children. Campanian lands might be held only by the fathers of at least three children.

[5] *Cf.* A. M. Carr-Saunders, "The Population Problem," pp. 147–149.

[6] E. M. East, "Mankind at the Crossroads," p. 45.

[7] C. E. Stangeland, "Pre-Malthusian Doctrine of Population," p. 30.

Most of the commonly assumed population policies of Rome, at least those which found expression in the laws of the later emperors, were anti-vice regulations, or provisions for the continuance of patrician families. Under the Emperor Augustus an elaborate code was enacted, looking toward (1) the preservation of class and privilege by forbidding persons of senatorial rank to marry persons of lower caste, (2) the promotion of marriage by handicapping legally the unmarried, (3) the further encouragement of marriage by granting legal and political advantages to married parents, (4) the further handicapping of unmarried persons by abridging their right of inheritance. These laws were, however, of little effect, not so much because upper-class Romans wished to avoid the burden of child-rearing but because they wished to indulge in all manner of irregularities. Finally, putting aside anti-vice legislation and laws designed to preserve class and privilege, we find the policy expressed by the remaining laws dealing with population to be the one made familiar by Roman literature and philosophy, a policy of expansion springing from the old instinct to prevail plus a reasoned policy of imperialism.[8]

The instinct to survive through sheer force of numbers seems to have been general among primitive and primordial peoples. So fundamental an instinct could not fail to find reflection in religious doctrine and practice. Professor Patten[9] and Dr. Stangeland[10] find that it did. In fact, primitive religions often made a fetish of the procreative act and gave it a central position in their ritual and doctrine. Of this Dr. Stangeland has to say:

> While it would be going too far to claim, as some writers do, that most, or even all, religions had a purely phallic origin, it can not be controverted that so-called phallic ideas have played a great part in very many early religions and religious ceremonies. The reproductive and fructifying powers of man naturally aroused his awe and reverence.[11]

Eroticism finds expression not only in the crude religions of primordial peoples[12] and primitive modern tribes, but also in the great philosophical and poetical religions of the East which have made themselves felt in effective opinion down to the moment that is passing. Bel, the supreme God of the Assyrians, was the great procreator. His wife Mylitta symbolized the reproductive passion of nature; she bore the title, Queen of Fertility. Hebrew scripture is full of the propaganda of prolificity; in fact, the first injunction of Jehovah to his highest and final work of creation was to "be fruitful."

The Brahmans affected celibacy as did the fathers of the early Christian church, but unlike early Christians they did not hold marriage in contempt, nor did they recommend abstention for the commonality of people.

The views of early Christians find a harmonious note in the asceticism of the precepts of Buddha, but as with Brahmanism, these precepts hardly touched the lower classes of their adherents.

Confucius' views very nearly coincide with those of the ancient Hebrew prophets and law-givers. His doctrine favored the expansion of population; he held that the man who died without sons died without honor.

Zoroaster pronounces with full, clear voice the precepts of productiveness in

[8] Varro, Ap. Macrob. "Saturn.," I, 16.
Horace, "Carmen Saeculare": "Diva producas subolem patrumque prosperes decreta super jugandis feminis prolique novae feraci lege merita."
Pliny, "Epistolae," vii.
Livy, Lib. i, Cap. 9.

[9] "Development of English Thought," pp. 132–133.

[10] "Pre-Mal. Doctrines of Population," pp. 40–44.

[11] *Op. cit.*, pp. 42–43.

[12] Westropp and Wake, "The Phallic Idea in the Religions of Antiquity," pp. 27 *ff.*

the Zend-Avesta: "Verily I say unto thee, O Spitama Zarathushtra! The man who has a wife is far above him who begets no sons; he who keeps a house is far above him who has none; he who has children is far above the childless man."[13] Herodotus tells us that in his time prizes were given in Persia by the king to those who had most children. Sacred texts of the Pehlevi period expressly declare that "He who has no child, the bridge of paradise shall be barred to him."[14] Mohammed seconds this doctrine—even exceeds it in recommending polygamy. He commands that special respect be paid to wives and mothers. (Stangeland, curiously enough, seems to hold that polygamy is less fruitful than monogamy, but he here is in face-to-face conflict with Mormon doctrine and experience.[15] Possibly he confused polygamy with polyandry or with promiscuity.)

Egyptians, Greeks, Romans and other Mediterranean peoples—but especially the Egyptians—in their religious thought and exercise held the reproductive powers in greatest esteem. Everywhere a prominent god or goddess represented the reproductive principle: in Egypt, it was Khem; in Assyria, Vul; in India, Siba; in primitive Greece, Pan—later Priapus; in Italy, Mutimus; in classical Greece and Rome, Venus, Priapus, Bacchus, Lucina.

Pilot's charitable, or at least agnostic, attitude at the trial of Christ, and Christ's previous pronouncement of allegiance to Rome, "Render unto Caesar the things that are Caesar's and unto God the things which are God's," to the contrary notwithstanding, Christianity was interpreted, both on the Roman and on the Christian sides, as a revolt, if not against Rome, then against a great many things Roman—and among others the low moral tone of the cosmopolis, especially in the matter of sex relations.

For early Christians, the celibacy of Christ and the virginity of the Holy Mother were ever-present symbols of a universal propaganda against prolificity. It was not, however, the austere scorn of the Brahman, it was not the preoccupied unconcern of the high-caste Mohammedan who was preparing himself, or his spirit, for a better life on earth—or somewhere not far off—it was the complete indifference to earthly acts of one who expected to migrate shortly to a happier and distant sphere. This was the teaching of Paul, the early church fathers and medieval Christians. Methodius says:

> For the world, while still unfilled with men, was like a child, and it was necessary that it should first be filled with these, and so grow to manhood. But when thereafter it was colonized from end to end, the race of man spreading to a boundless extent, God no longer allowed man to remain in the same ways, considering how they might now proceed from one point to another and advance nearer heaven, until having attained to the greatest and most exalted lesson of virginity they should reach to perfection; that first they should abandon intermarriage of brothers and sisters and marry wives from other families; and then that they should no longer have many wives, like brute beasts as though born for the mere propagation of the species; and then that they should not be adulterers; and then again that they should go on to continence, and from continence to virginity, when, having trained themselves to despise the flesh, they sail fearlessly into the peaceful haven of immortality.[16]

Sir Thomas More in his "Utopia" takes a stand midway between Methodius and Luther—a view that was filched, we suspect, from Plato: "Lest any city should become either too great or by any accident be dispeopled, provision is made that none of their

[13] Z. A. Ragozin, "Media, Babylon, and Persia," p. 123.

[14] *Loc. cit.*

[15] C. E. Stangeland, "Pre-Mal. Doc. on Pop.," p. 49.

[16] Methodius on virginity, recounted in H. Wright, "Population," p. 6.

cities may contain more than six thousand persons besides those of the country round."[17] Plato in his Utopia recommends, we recall, five thousand and forty people. But good Sir Thomas apparently counts upon a terrific death-rate: fourteen out of every sixteen children must meet an untimely end if each couple is only to reproduce itself, for he says: "No family may have less than ten or more than sixteen children, but there can be no determined number of children under age."[18] But with the appearance of Luther and the Reformation, rising reverberations merged in a clear, unmistakable and wholly different note. From that time forward, Christians and the people of Christian civilization took their population policy for four centuries or more from the Old Testament, from the Pentateuch and especially from God's command to his first-made man. Luther sounds the full note of unlimited expansion:

> It is only necessary that we work and do not remain idle; we shall assuredly be both clothed and fed. . . . From all this we draw the conclusion that whoever finds himself unfitted to remain chaste should make arrangements betimes, get some work and then dare, in God's name, to enter into matrimony. A youth should marry not later than his twentieth year, and a maiden when she is between fifteen and eighteen years old. Then they should remain upright and serious and let God provide the way and means by which their children shall be nourished.

In another place good Luther says, "If women bear children until they become sick and eventually die, that does no harm. Let them bear children till they die of it; that is what they are for."[19] This is the view of the "he-Christian" intoxicated by the poets and *cognoscenti* of Hebrew scripture. This, with the military accompaniment of rolling drums and blaring trumpets, is a very ancient hymn to those genial gods who whisper in the ears of solemn males that the procreative act is a religious duty—willy-nilly.

The Thirty Years' War, which decimated the population of the heart of the continent of Europe, and the rise of Louis XIV and his like to play a while at the engaging game of Grand Monarch, brought a need for cannon fodder—for many men, brave or not brave, sons of otherwise happy peasants and happier gentry who might serve as chips, white, blue or gold, in this expensive and correspondingly gratifying play among the *L'état-c'est-moi* players.

But before the arrival of the Grand Monarchs and their successors, the Great Powers, there was a period of desiccating poverty which produced in Bacon and Sir Walter Raleigh a conservative strain. Raleigh, even when discoursing upon war, said:

> When any country is overlaid by the multitude which live upon it, there is a natural necessity compelling it to disburden itself and to lay the load upon others, by right or wrong, for (to omit the danger of pestilence, often visiting them that live in throngs) there is no misery that urgeth men so violently unto desperate courses and contempt of death as the torments and threats of famine. Wherefore, the war that is grounded on general remediless necessity, may be termed the general and remediless or necessary war.[20]

But usually militarists held no such apologetic view.

German theorists of the time and later, mostly court stewards or *Finanzminister* with a philosophical turn of mind, economists to an extent—called Camerialists—fell in with the militaristic procession, and urged policies of population expansion.[21]

[17] Sir Thomas More, "Utopia," p. 102, "Ideal Commonwealths."

[18] *Loc. cit.*

[19] Preserved Smith, "The Age of Reformation," p. 509.

[20] Sir Walter Raleigh, "Doctrine Upon War in General."

[21] L. H. Haney, "History of Economic Thought," pp. 138, 147, 148.

The Mercantilists, another school of pre-economics economists, prescribed expanding populations. The rise of great powers and of mercantilism are merely the economic and political aspects of one and the same phenomenon. Huge states competed for the material good things of life and for the privilege of exploiting the alleged backward peoples of the world. For three hundred years the pale men of the earth outdid each other in seizing and in plundering. All this took men and money, but mainly men. The sages of the hour, who for the first time in the history of the world were in their several individualities one and the same person with the merchant princes, wrote very engaging essays setting forth the glories of large families. William the Third, heeding their advice, taxed bachelors, as did Colbert—Louis XIV's unexampled master of extortion. British colonial legislation a little later had a like inclination; for example, the colony of Maryland enacted that unmarried men, more than twenty-five years old, and childless widowers of the same age should, in certain circumstances, pay a tax to be applied to the support of foundlings. Prussia at this time required marriage before the age of twenty-five, and subsidized the institution. Maria Theresa of Austria broke tradition and permitted soldiers to marry. In 1767, she decreed a bounty to sergeants, corporals and common soldiers of three *kreutezri* per diem for each legitimate child.[22]

Writers and theorists to justify such programs were not wanting. The motive expressed in theory and practice alike was plainly an extension of the instinct of self-preservation, a desire for world dominance, a militaristic doctrine; argument nevertheless ran in economic terms. These theorists, doctrinaires, observers and writers noted that where wealth was abundant there were people in great numbers; and they came by an easy pathway to the conclusion that more people meant more wealth, that if a nation or a great city wished to be wealthy, it must encourage the multiplication of population. Truth, of course, runs in a direction exactly opposed to their stream of thought: the existence of great wealth, or the existence of unusual facilities for the development of great wealth, draws an abundant population.

John Graunt (1620–1674) in his "Natural and Political Observations Upon the Principles of Mortality" says:

> Now forasmuch as princes are not only powerful but rich according to the number of their people (hands being the father as lands are the mother and womb of wealth) it is no wonder why states by encouraging marriage and hindering licentiousness advance their own interest as well as preserve the laws of God from contempt and violation.[23]

Sir William Petty (1623–1687) spoke unmistakably in favor of the multiplication of population, and considered it the most definite sign of prosperity. In his "Political Arithmetic" he recognized a relationship between the growth of wealth and the growth of population. In his "Treatise of Taxes and Contribution" he associates population and wealth more definitely, giving population a causal character. "Fewness of people is a real poverty," says this noble scholar, "and a nation wherein are eight millions of people is more than twice as rich as the same scope of land wherein are four." John Locke seconds this opinion—though Locke's vigorous individualism made him more nearly the father of the natural liberty or physiocratic school of economists than a follower of the mercantilists, from whose technique physiocracy was in part, of course, a reaction.

[22] C. E. Stangeland, "Pre-Mal. Doc. of Pop.," pp. 124–126.

[23] P. 70.

Thomas Mun (1571–1641), merchant prince and popular pundit of political economy, was one with his mercantilist colleagues in advocating swarming populations: "For when the people are many and the arts are good, there the traffic must be great and the country rich."[24] Samuel Fortrey (1622–1681) and Sir William Temple (1628–1699) follow the crowd: "The true and natural ground of trade of nations is the number of people in proportion to the compass of the ground they inhabit."[25]

Sir Joshua Child (1630–1699) was an ardent believer in the advantages of a mounting population. He felt quite certain that an increase in numbers meant increasing riches, and that any decrease in population would bring about a decrease in wealth. In brief, all the great mercantilists recognized a direct relationship between population and wealth, but all of them put the cart before the horse: all of them held that population was cause and wealth, effect. Sir Charles Davenant (1656–1731), McCulloch and Adam Smith, however, seem each to have gained a progressively clearer insight into the correct view that wealth was the cause and population the effect.

Benjamin Franklin, who was born an Englishman but afterward became an American citizen, was in thought and spirit always a Frenchman. Nowhere—not even in America—was he so fully appreciated as in France. Franklin was greatly influenced by the then current school of French economists, the Physiocrats. The great American sage, in his "Observations Concerning the Increase of Mankind and the Peopling of Countries," says something which sounds very much like Malthus:

> There is no bound to the prolific nature of plants or animals, but what is made by their crowding and interfering with each other's means of subsistence. Were the face of the earth vacant of other plants, it might be gradually sowed with one kind only, as, for instance, with fennel; and were it empty of other inhabitants, it might in a few ages be replenished from one nation only, as, for instance, with Englishmen.[26]

Here undoubtedly is the most significant writing upon the subject of population or upon the much broader subject of biology, for that matter, before Malthus; for Franklin's principle, if not the actual progenitor of the cataclysmic ideas of Malthus, Darwin and Wallace, contained their essential element.

In 1776, the first year of American independence and the year of the first practical substitution of steam-power for man-power, Adam Smith issued his great work, "The Wealth of Nations." Smith, like Holy Writ, is notorious for furnishing quotations to any devil who passes: Karl Marx's thunder is an echo from the "Wealth of Nations," nevertheless it has been a rich source-book for reactionaries in every land. Smith's pronouncement upon population possesses this same dual character.

But in the main, Adam Smith takes the view of the out-and-out mercantilist, the militarist, the churchman: "The most decisive mark of the prosperity of any country is the increase in the number of its inhabitants." Farther on, however, we find the slightly Malthusian pronouncement: "Countries are populous, not in proportion to the number of people whom its produce can clothe and lodge, but in proportion to that of those whom it can feed," and then what seems to be the very essence of Malthus' great essay, "Every species of animals naturally multiplies in proportion to the means of their subsistence

[24] Sir Thomas Mun, "England's Treasure in Foreign Trade," p. 12.

[25] Sir William Temple, "An Essay Upon the Advancement of Trade in Ireland," Vol. III, p. 6, of "Work's" (1757 ed.).

[26] "Works" (Bigelow edition), p. 347.

and no species can ever multiply beyond it." As an effective basis for the great Darwinian hypothesis which, as every schoolboy now knows, was filched directly from Malthus, this statement is, however, wholly inadequate—in fact, it is the exact opposite of the Malthusian thesis: all species tend to multiply *beyond* the means of their sustenance—whereas Smith says, "No species can ever multiply beyond the means of their subsistence." This was the last significant voice heard before 1798 when the great essay on the principles of population was uttered by Malthus.

Hume, Wallace, Dr. Franklin and Adam Smith—these were teachers of Malthus, but pupil exceeded masters. William Godwin, the latter day saint and proponent of perfection, was the man who incited the revered, and ordinarily mild, Mr. Malthus to break into argument with his father, who was an ardent Godwinite and a follower of Rousseau. The elder Malthus and Godwin, with their irrepressible and distressing optimism, stirred in young T. R. Malthus a bit of irritability which gave the world—if we remember the debt of Darwin and Wallace—the most influential piece of writing to which it has ever fallen heir. For upon its central thesis (life everywhere tends to exceed the warrant for it) rest principal propositions in nearly all departments of modern philosophy and science.

A BLACK BEAST IN OUR EDUCATION?

By Professor GEORGE MALCOLM STRATTON

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At a recent conference upon the scientific study of young children—a conference of leaders from the United States and Canada—the presiding officer warned the members against an attempt to get rid of crime. He believed that such an aim would bring danger of utter fixity, of utter stagnation, in the country. And he had in mind, I know from immediate conversation with him, President Hoover's call upon America to become a law-respecting instead of law-flouting nation. Another member of the conference, one of the most distinguished of the women present, who had recognized the need that children should early adapt themselves to the requirements of their society, aroused instant opposition because of this restriction upon the child's full liberty. Under fire, she at once protected her position and agreed that in teaching the child to obey law, the child must above all be taught to know when to break law.

Such views, even if extreme, illustrate a trend in American education in the home, in the school and in the larger community. It has long been with us, giving color to the opinion of foreigners that we have the world's worst-behaved children. Indeed, we should probably have to go to the Eskimo to find boys and girls as self-willed as ours. The national commission to report to the President upon the violation of law in America will of course look into, but also beyond, the laws themselves and the lawyers, judges, police and the procedure of our courts. If thorough, their observant eye will stay long with the children, and not simply with delinquent children. For the attitude even in those who keep the laws, an attitude established in early life, is important. An attitude in the public generally toward law, toward all restriction of individual liberty, affects our education, which in turn confirms the attitude in the public generally and invites license.

Now this trend in our education has received fresh impetus from studies of repression. Under the influence of Breuer, Freud and others this field has been given a new significance for mental and physical health and for emotions and for character itself. And in consequence there has come the desire to rid the young of their harmful repressions, to avoid a paralysis of the youthful spirit, to encourage initiative and the free expression of personality. Behind this massed attack upon evils too often in the family and in the schools, evils which all liberal minds will wish destroyed, there is an eagerness for a new form of liberty.

And yet in this right eagerness, we might receive the new sensibly. We might contrive, like an older child, to hold things in two hands at once. In our impulsive delight in the novel benefit from unrepression—especially when this chimes so well with our national zeal for freedom—we may find ourselves like a hungry and thirsty dog that, suddenly coming upon water, drops his bone in the deep pool to drink and then discovers that he still is hungry.

Now in the admirable ardor for individual freedom and self-expression in childhood, one too often misses an equal ardor for the conditions which make for freedom and self-expression. One might imagine, from the long tale of wrongs wrought by parents and teachers, that the happiest place for the personal development of the young would be the jungle. Fortunate the child, one might believe, whose wise father and mother had in infancy abandoned it to wolves or apes. But such jungle children as are actually observed, say in India—are they

of all the young the freest in their powers, liberated, clear-eyed, masters of their fate, captains of their souls? On the contrary, they seem more like beasts than men, without the human gait, mentally like imbeciles. They seem to have nothing of personality to express, and no means to express this nothing. Kipling's Mowgli of the "Jungle Book" is a noble figment of an unprecise imagining. It is neither fact nor truth. Romulus and Remus, if given no more than their native impulses, trained after the manners of their foster-mother, would have been impossible founders of the Eternal City and of that great Roman culture of justice through law which changed the face of Europe and America.

The truth is, that spiritual attainment is only in part to be prepared for negatively, by removing inhibitions, by avoiding repression. The qualities which are most valued in the person—his intellectual penetration; his escape from superstition; his creative power in arts such as literature, painting or music; his tolerance of opposition; his broad interests and sympathies; his contempt of lies; his unswerving loyalty to child, wife, country, humanity; his readiness to go to the stake or the block or to drink hemlock, for his scientific or moral or religious convictions—these are not to be had merely by removal of external obstacles; the man, the woman does not spontaneously come into these great traits by sheer individual growth or maturing. On the contrary, along with the removal of external obstacles and with the happy growth, these things come only by creative achievement in a community whose eyes, generation after generation, are fixed upon their achievement, and who invite and praise and whip one another onward in the great corporate enterprise. This is why no Dante, no Darwin, no Beethoven steps forth from the jungle. Liberty is not enough. Ages of constructive work by men and women forgotten entered into the great attainment by these and all other geniuses. Creative power obtains its knowledge, its skill, its interests, its aims, its appreciations, nine tenths from others. The personality that comes to such original expression is nine tenths a creature of the spiritual city in which it lives. Both genius and talent, to change Goethe's saying, require the storm of the world. Even your relatively detached critics, like Descartes and Voltaire, are no less the children of a surrounding and sustaining enterprise than are the more attached geniuses like Wesley or Lincoln.

In our American life and schooling we rightly recognize the evils of repression, but we need not think it the blackest of beasts. Most of us who are healthy can stand much repression—finding it uncomfortable, perhaps, but without lasting damage. I sat by a lady at dinner a few days ago who spoke to me bitterly of her early training. Her childhood had been so repressed by a rigid Presbyterianism that when recently she was in Geneva she could take no pleasure in the Reformation Monument there, with its stately sculptures, its inscriptions, its noble planting, because she discovered John Knox among its heroes; and in Edinburgh, as she passed his house on the High Street, she could only stick out her tongue at it! I listened sympathetically; I was glad that I had escaped her kind of training. And yet I could not but see that, with all the wrong done her childhood, hers was not a frustrated personality. She had done and was still doing enviable things. Her early discipline, dour as so much of it was, had given her far more than it had taken away: she knew and loved things honorable, she was both zealous and sane in her work for social betterment, and had subjected her high intelligence to a training which had given her an expert leadership recognized by all those in her kind of work throughout the nation. She undoubtedly had been made less happy, but had not been crippled by

those early years. Unfortunate as they were, they were ten times less unfortunate than would have been the untrammeled life of the gutter snipe.

The slight damage which the normal person usually receives from such repression as is part of intelligent and fairly sympathetic discipline can be seen if we look to a larger company. It has long seemed clear that ministers' sons generally go wrong; cases in plenty can be cited by any one; and it stands to reason that it must be so, for these lads are made rebellious by home austerity. And yet, the facts, when gathered impartially and on a wide scale, show the very opposite; show that ministers' sons are in a highly favorable situation. What an actuary might call their "expectation" of becoming distinguished is better than that of most others' sons. Above the children of laborers, farmers and artisans, in this respect, come the children of business men; and above these stand the children of professional men. And within this highest class the sons of clergymen are no whit behind the rest. Even doctors and lawyers give no higher quota of children who come to attainment. In spite of the economic straits in which clergymen's families are reared; in spite of what the anti-repressionist might call their utter damnation from snivelling Presbyterianism, Baptism and Methodism, the ministers' households have proved to be nurseries of talent; in general, we have contrived none better. Repressions have been there on every hand. To the unpenetrating observer the air seemed heavy and stifling, from basement to attic. And yet something was present in the homes of these children which really gave them freedom, liberating in them what their fellows were to recognize and praise. Repression, then, while always uncomfortable and sometimes disastrous, is not the great source of disaster; it is not the reef on which most lives are wrecked. It is not the one fact in childhood to be feared above all else.

Obviously repression is not the chief cause of crime; although in saying this, one stems a latest current of the tide. The trends of thought here shift twice daily, as though controlled from the moon. Only yesterday was law-breaking attributed mainly to degeneracy with certain clear physical marks. But this theory suffered because too few criminals and too many law-abiding persons had these very marks of degeneracy. Then crime, it was said, is due first of all to poverty. Yet too often we find young violators whose parents are by no means in poverty; indeed, America, the wealthiest, the least necessitous of lands, leads the world in crime. Still later the cause is thought to lie in lack of intelligence; until facts put this, too, in its place. For too many of our criminals, young and old, have as high intelligence as those who obey the laws. The most of criminals indeed have an endowment of intellect quite adequate to lawful living in our civil order.

At the moment, we hear of repression as the chief cause of crime, especially in the young. At the annual convention of the National Parent-Teachers' Association in New York recently, a professor of sociology spoke in the newest vein, telling the great gathering of delegates, more than a thousand strong, that the excesses found in the youth of to-day are but a protest against coercion in home and school. And at the far smaller conference of experts in child development, already mentioned, the same thought was expressed, that delinquency is due chiefly to repression.

Now if this were true, if in this the chief cause had really been disclosed, then America should be the most law-abiding of lands. For our children in home and school are the least repressed in the world. And it is precisely our young criminals who have experienced

for the most part less than the least parental repression among us. The great part of them have known no real home at all, but early were waifs and strays.

And here we come into view of the one most important of all the causes. Other facts doubtless weigh—inferiority of physique, poverty, feeble-mindedness or mental disease—but the one fact which by direct observation in school and juvenile court enters oftener than any other is a lack of such training as comes from the normal home. This training is not mere knowledge, to be picked up in the house or street or newspaper or public library. It is not to be had, one regrets to say, in school, even in the advanced school; for the graduates of high school or college or university may not have received it, and far too often despise the social order. The unbroken home is its chief single source; and with all the charges to-day against homes and parents, no equal substitute has yet been found for the plain home and the plain mother and father. Unnecessarily and even harmfully they may repress; and yet commonly they more than offset whatever damage comes from their repression. The more profound and permanent injury to the child comes, not from the normal home or school, but from those cracked shells of home and parentage where the child finds the least restraint and is trained into no sure habit and purpose. He goes through life with chaotic impulses, which once might have been given form and beauty.

We may quite properly be afraid, then, of repression, but still more may we fear weedy personal growth without repression and guidance. Indeed in our present education, behind which is our traditional zeal for liberty, the greater danger is that we shall over-prize personal freedom and under-prize the benefits which come only from a civilized social order itself. In our lower and higher schools we are tolerant of slovenly conduct, speech and thought because these seem to betoken independence and self-resource. And because law-breaking seems a sign of this same admirable attitude, we are too little repelled by law-breaking and unwittingly foster it. Crime in quite extraordinary amount springs from the practical bearing so common with us, namely, that each person may properly regard himself as the supreme fact, for which the rest of the world is but a limiting condition. Men, women and things, he feels, are but stimuli for his responses.

We shall never be radical toward law-breaking until we destroy these roots; or rather, until we grow others strong among them. In school and home we shall have to give our youth a rooted attachment to the heart of the social enterprise itself. At present among teachers, scientists and laymen, the person is encouraged to see in the order and institutions of society but flimsy conventions, to be brushed aside like cobwebs in his way. He becomes boorish toward the subtle assistants of his life. He grinds his hob-nails into the most delicate fabrics of the spiritual loom. All things but his own crude spontaneities he regards as "bunk." Our educational creed in the quarters fashioned by a one-sided individualism is to-day as narrow as those creeds of Protestantism yesterday in which the individual thought of little but himself. It all bears a repulsive egoism. Mr. Haldane has recently said that the self-made man of America seems to the European somewhat ruthless. One may venture to think that there is a certain ruthlessness in Americans not self-made but shaped by our schools and by our American spirit generally. We have never as a nation quite reconciled liberty and law, but each man is airy toward any regulation inconvenient to himself. Americans are not convinced of the need—and the teacher-leaders most in vogue are taking away what little conviction there is of the need

—of loyalty toward such culture and cultural institutions as we have attained, still defective though they are.

For only by a cultural order which centuries and millenniums were needed to create, and by the institutions of such an order, do we attain the very individuality, the very originality we prize. The eminent danger with us—not only to our laws, but also to our success in literature, art, morals and religion—lurks in the ruthless form of our individualism—a form essentially wasteful of the individual because he is left untrained in expression and without substance to express. In those regions where we Americans succeed most impressively — in wealth-making, in architecture and in science—our success comes by another attitude, not by swagger of individuality, but by individuality essentially moderated, tempered into respect for an order of things beyond the individual. Our marked achievement in amassing wealth, in building and in scientific discovery and application has come and comes from creative individuals, but from individuals who have had to submit to a great order outside themselves; who consent to it and find their consent is not an enemy but a friend to their self-expression. By their very submission, strange to say, they find themselves enfranchised and given the freedom of the realm.

This attitude to be observed where originality most thrives is seen to involve an essential repression, but a repression which because it is in some deep manner accepted and approved and knit without rift into the personal structure is also without lasting protest and paralyzing rebellion. The weedy impulses—of the merchant to take what he wants, regardless of trade principles and ownership; of the architect to build without heed of cost or use; of the scientist to follow his own sweet will and peer into things irrespective of their significance for other minds, and to explain irrespective of other facts and of the canons of induction—these weedy impulses, where we have achieved most, have been handled in a manner which Rousseau and Professor John Dewey and their near or distant followers might with difficulty approve. The native impulses have been given an unnatural form, a form of social art. The spontaneous here has thrived, but has had to make its peace with an external law and order.

Our education, if it is to come to fruition, then, must recognize how glib and shallow is much of the patter about restraint. There are repressions and repressions; and of some we must get rid, and to others we must add strength. There is no place here for wholesale dreads and rejections. At a certain point one must plant his intellectual feet, and like some old schoolman abruptly say *distinguo*. The undiscriminating talk to students, parents and teachers—as though children burst into bloom by mere removal of constraint—such talk comes of loose thinking, of inexact observation and of that glamour which a kind of anarchy has for some noble minds. The spiritual anarchist for whom all external law is bondage has a good case, but hardly good enough. America surely need not stagnate or become enslaved merely by becoming more respectful of law, whether it be in home or school or nation—she with her larger margin of safety in this respect than any other country. She can become even more free and creative, and at the same time more order-loving. And only by education can this be done. So that the outlook will be dark indeed if teachers and parents are bedeviled, by a limited truth of psychology, into a panic fear of all governance of the child. The least repressed of peoples need not make repression their bugbear. The very freedom of the young can not be attained except by what must involve some repression; and if this becomes our *bête noire*, we are apt to diminish rather than increase the full round of things propitious for our children.

SUNLIGHT AND ITS MANY VALUES

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Dove non entra sole, entra il medico.—Italian proverb (Where the sun does not go, the doctor goes).

THE sun has ever exerted a profound influence on mankind. To the race in childhood the sun was a god. In the old mythologies the sun was personified and given human attributes. It was also believed to be the chariot wheel of a vehicle driven by the sun-god, Phoebus Apollo.

Sun worship is not a thing of the past altogether. There is yet extant a religious sect in Persia that still adheres to the practice. The American Indian still carries on his sun dance and prays to the great Sun Power. The soulful prayer of the Shoshone chief living on a reservation near Pocatello, Idaho, reveals the faith held in the potentialities for happiness and health possessed by the sun:

> Great Sun Power! I am praying for my people that they may be happy in the summer and that they may live through the cold of the winter. Many are sick and in want. Pity them and let them survive. Grant that they may live long and have abundance. May we go through these ceremonies correctly, as you taught our forefathers to do in the days that are past. If we make mistakes pity us. Help us, Mother Earth, for we depend upon your goodness. Let there be rain to water the prairies, that the grass may grow long and the berries be abundant. O Morning Star, when you look down upon us, give us peace and refreshing sleep. Great Spirit, bless our children, friends and visitors through a happy life. May our trails be straight and level before us. Let us live to be old. We are all your children and ask these things with good hearts.

Sunshine is a very old remedy. The same instinct which led ancient people to worship the sun as a god led them also to a belief in the therapeutic value of sunlight. Since the earliest times men have recognized the value of sunlight in the prevention and treatment of disease. The ancient Egyptians recognized sunlight as a healing agent. On the island of Cos in the Greek Archipelago, where Hippocrates, the father of medicine, practiced, the citizens erected a health temple and dedicated it to Aesculapius, god of sun, medicine and music. The colossal statue at Rhodes was a monument to the sun-god, Helios. The Romans built sun parlors without windows. Coelius Aurelianus, a Roman physician, advised the use of sun baths in chronic affections. To Pliny has been attributed the statement: *Sol est remediorum maximum.*

Oribasius of Pergamum, who lived during the last quarter of the fourth century and who was the physician of Julian, quotes Herodotus as follows:

> The sun is especially necessary for people who need restoration and the increase of their muscles; yet one must be careful of the rays which first pass the clouds, and avoid the rays which collect in places protected from the wind. One must further take the precaution that in winter, spring and autumn, the sun strike the patients direct; in summer this method must be avoided with weak people; the head must be covered during the treatment.

From this interesting statement it seems that the Greeks had laid down specific directions in the sun treatment of the sick. The use of sunlight as a therapeutic agent was known to the Arabians. Avicenna, the famous Arabian physician, who was a poet and who is believed to have participated in creating the Rubaiyat, also favored sun treatment in disease.

The method of treatment through sunlight was sooner or later discarded and sank into oblivion. It was revived again about the eighteenth century. Unfortunately, it was at that time regarded as a means to be used only by the quack. To illustrate the regard in which heliotherapy was held, we may cite the case of a physician well known in his day, Dr. Lettsum, who prescribed sun baths in the treatment of tuberculosis. He founded the Royal Bathing Hospital at Margate, an institution for the treatment of surgical tuberculosis, which still continues its beneficent activities. He received from his colleagues nothing but laughter and derision. There is a little poem about him that indicates their attitude.

> When patients come to I
> I physics, bleeds and sweats 'em
> And if they choose to die
> What's that to I? I Lettsum.

In 1774 Faure advocated exposure to sunlight for the treatment of chronic ulcers of the limbs. In 1815 Chauvin published a work on "Insolation" in which he urged the use of the sun for all diseases associated with feebleness, exhaustion and apathy. The names, however, that stand out most conspicuously in actinotherapy and heliotherapy are Finsen and Rollier. It is mainly through their efforts that it has come to be recognized that sunlight itself or the ultraviolet ray is a very important factor in the treatment of disease and in the development and maintenance of health.

The advent of the sun in scientific medicine is no less glorious than that of the microscope, antisepsis and anesthesia. Its reintroduction into modern therapy is a decided contribution, and constitutes a whole new chapter in the history of medical progress.

The first modern institute for the scientific treatment of disease by means of light was established by Niels Finsen in Copenhagen. For years his work remained unnoticed and unappreciated. After the publication of his book, "Chemische Lichtstrahlen in der Medizin," physicians gradually turned their attention to his methods. Finsen demonstrated beyond doubt that lupus vulgaris, that is, tuberculosis of the skin, can be cured by the action of ultra-violet rays on the affected parts. When Finsen died in 1904 his work had become sufficiently recognized to induce the Danish government to establish the Finsen Medical Light Institute. It is now directed by Dr. Axel Reyn and continues to be a center of attraction for physicians and patients the world over.

Another mighty personality that looms large in the development of sun treatment is Dr. A. Rollier. In 1904 he established an institute for treatment by sunlight. It is situated in Leysen in the Ormonts Valley of the Swiss Alps. His famous sun baths have proved most beneficial to sufferers from chronic ulcers, from anemia and rickets, and from several forms of tuberculosis of the skin, bones, joints and glands.

Rollier has gone even a step beyond attempts to cure. He has entered the more vital field of prevention. Children with reduced powers of resistance brought on by various diseases such as measles and whooping-cough, who are in danger of developing tuberculosis, are boarded at the Rollier school. They conduct their studies in the open air for two hours every day and with clothes consisting of no more than a loin cloth, linen hat and a pair of shoes. They rest for two hours every day and fill in the remainder of their time with nature study and Swedish drill.

Let us delve a little into the nature of sunlight. The ether is traversed by a great variety of electromagnetic waves of various length. The longest of these are the Hertzian waves, the so-called radio waves which possess the ability to carry sound into every home. These

waves may be many miles in length. They are invisible. The next shorter variety of wave-lengths are the infra-red rays of the spectrum. Still shorter waves are the ultra-violet rays and yet still shorter in wave-length are the luminous rays of the sun. The shortest rays are the X-rays or Roentgen rays and the gamma rays from radium.

The unit of measurement adopted for measuring the wave-lengths of various rays is the Ångstrom unit, which represents one ten-millionth of a millimeter. The table below gives the wave-length of the different kinds of rays known.

Kinds of rays	Wave-length Ångstrom unit
Gamma rays from radium	0 to 0.1
Roentgen rays	0 to 500
Extreme ultra-violet radiation	0 to 2,000
Middle ultra-violet radiation	2,000 to 3,000
Near ultra-violet radiation	3,000 to 4,000
Visible radiation	7,800 to 5 million
Electric waves, wireless telegraphy, radio waves	5 million units to miles

The emanations from the sun make up a mixture of rays of different wave-lengths. The sun's rays are either visible or invisible. Newton made the pioneer observation that what is called white light consists of a variety of colors, the familiar spectrum when light is passed through a prism. One color differs from another only in wave-length. The white light or visible spectrum is only a portion of the rays coming from the sun. Beyond the visible red rays there is an invisible infra-red region made up of waves of much higher wave-length than the rays of the visible spectrum. Beyond the visible violet rays, there is the ultra-violet region with rays much shorter than the rays of the visible spectrum.

The visible rays produce light and constitute about 14 per cent. of the sun's total spectrum. The infra-red rays produce heat and constitute about 85 per cent. of the sun's output of radiant energy. The ultra-violet rays are the chemical or actinic rays and make up only 1 or 2 per cent. of the sun's rays. The visible portion of the spectrum may be completely shut off, but if a photographic plate is placed in the ultra-violet region it will still become sensitized. The therapeutic properties of sunlight are now believed to reside largely in the ultra-violet rays, although it can not be denied that the infra-red rays as well as the luminous rays are also important from a biologic standpoint.

The quantity of ultra-violet light that reaches a person depends upon many factors. The ultra-violet rays are very readily absorbed. In order to get their biologic benefits very little should interpose between the sun and the surface of the body. Clothes may prevent the ultra-violet rays from reaching us. The shoulder strap of the bathing suit keeps the skin underneath from tanning. Porous, thin and loosely woven clothing presents to us a better chance for the appropriation of these rays. The type of clothes worn by women is better adapted to the reception of ultra-violet from the sun's rays than the type of clothes worn by men.

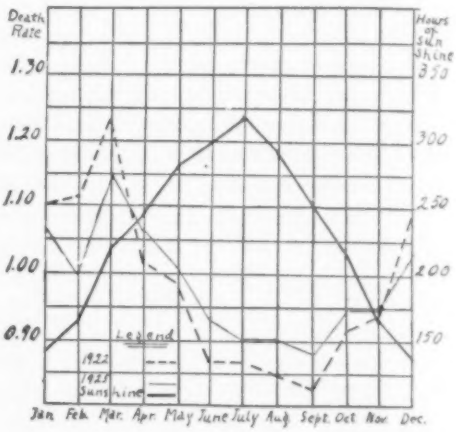
Impurities in the air also conspire to filter out ultra-violet rays. The great offenders in this respect are smoke, fumes, dust, bacteria and moisture. In an industrial center, therefore, less ultra-violet is bound to reach the surface of an individual.

Ordinary window glass lets in the luminous rays but unfortunately excludes the ultra-violet rays. A sun parlor with windows closed is useless so far as the therapeutic value of these rays is concerned. Although ultra-violet prevents rickets, white rats kept in glass

boxes exposed to bright sunlight, nevertheless, develop this disease. In the last few years new types of window glass have been made. These are now being used in some hospitals and sanitaria. A hotel in Chicago has recently equipped its guest rooms with this new type of window glass. There is no doubt that in the very near future the old window glass will be universally discarded for the glass that allows the ultra-violet rays to pass through.

The amount of ultra-violet that finally reaches us depends also on the season of the year. There is much more ultra-violet in the summer months than in the winter months. In July and August the ultra-violet content of sunlight is of maximal value. In December and January the ultra-violet content of the sun's rays is minimal or less than 5 per cent. of its maximal value.

Lack of ultra-violet is believed to be partly responsible for the increased rate in sickness and death during the winter months. The sun is practically darkened for more than half a year. As a result of indoor living brought about by inclement weather during the winter months, the little sunlight available is hardly utilized at all. It is the lack of sunshine that is responsible at least partly for people weakening physically during the winter months and succumbing easily to disease. Pneumonia, influenza and the common cold are most prevalent in those regions where and in those seasons when there is least sunshine. The statistics kept by the U. S. Department of Commerce show an interesting interrelation of mortality rate to sunshine hours. Plotting the curve for death-rate and sunshine hours, let us say for the years 1922 and 1925, we see at a glance that the death-rate increases as the months grow darker and decreases as the sun returns. Even spring fever with its feeling of aimlessness and lassitude arrives at the end of a long period of practically sunless days. The feeling is often noted on rainy or foggy and cloudy days during winter or any other time of the year and is often described as the under-the-weather feeling. It very often disappears with the coming out of the sun.



RELATION BETWEEN MORTALITY RATE AND SUNLIGHT

The fact that the winter months are accompanied by a marked increase in morbidity and in mortality should lead us to the use of artificial sunlight during those months. Especially is such use indicated for people with subnormal vigor and health. Maughan and Smiley have shown that during winter months treatment with ultra-violet reduces the incidence of the common cold about 40 per cent.

Sunlight has many values. It adds considerably to general well-being. It improves the body metabolism. No plant, animal or human being could live without it. It invigorates physically. It enhances mental powers and brings to the front the more positive and stimulating emotions.

The sun's golden lancers
Were watching the dancers
Down in the meadow one day,
When the buttercup said,
"I'll wager my head

I'm brighter than you are to-day."
"And what do you think"
Said the beams with a wink,
"Has made you so strong and so gay?"

Sunlight is a powerful bactericide. It also plays a great part in the development of immunity. It raises markedly our resistance to local or general infection. It helps to build the hemoglobin and the red cells in the blood, and it serves to keep the coagulability of the blood up to normal. It improves the excretory function of the skin, giving rise to a healthy skin, soft, velvety and slightly moist. It keeps the muscles and nerves of the body in tone. It therefore gives bodily poise and prevents overweight. Sunlight is God's way of preventing disease.

Some look for health in pills
And some in rules;
Some grope for it in stuffy,
Cheerless schools,
But from the wind-swept fields,
A voice proclaims
"Your health lies neither there
Nor there, O fools."
Oh contemplate the lilies,
Look I say!
And chase your patent
Humbugs quite away,
The sun had spread her
Golden vesture down,
And bids you to her picnic,
Come and play!

Sunlight has proved of great value in the treatment of disease. Medicine is getting away from drugs. As a matter of fact, the pharmacist is now compelled to make a living by selling articles other than drugs. The prescription counter now occupies a little obscure corner of his establishment. We are getting to rely more and more for the maintenance of health or for recovery from disease upon the three greatest of modern physicians, Dr. Sunlight, Dr. Diet and Dr. Quiet. In tuberculosis, in infantile tetany, in rickets and in anemia, sunlight or ultra-violet has remarkably favorable effects. In the treatment of chronic ulcers of the limbs, and in skin infections, such as acne, boils, carbuncles and lupus vulgaris, sunlight or ultra-violet also serves as a very efficient therapeutic agent. Whenever a tonic is needed, as in acute infection, in convalescence, in muscular weakness, in anemia, in general debility and in neurasthenia, sunlight or ultra-violet can be used to great advantage. In short, sunlight or ultra-violet is a very valuable aid to the progressive physician. We may also state that the infra-red rays are effective in the treatment of muscle pain, rheumatism and arthritis.

In the preparation of a patient for a major or minor operation, sunlight or ultra-violet treatment should hardly be omitted. In the event of a low serum calcium and low platelet count, it raises the coagulability of the blood by increasing its calcium content and the number of blood platelets. It thus prevents excessive losses in blood through unnecessary hemorrhage. By raising the alkaline reserve of the blood it may prevent the post-operative nausea and vomiting, which are symptoms of acidosis. The liberal use of carbohydrate, calcium-rich foods and sunlight or ultra-violet helps very much to prevent risk resulting from surgical intervention.

We have one vitamin, the anti-rickets vitamin or fat-soluble D, that acts biologically in the same manner as the ultra-violet rays. It can, therefore, cure or prevent rickets. This vitamin is not widely distributed in foods and is not very abundant. It is found especially in such fats as are contained in egg-yolk and in liver. Cod-liver oil is a very good source of this vitamin. Vegetable fats have none of it. Recently it has been discovered that exposure to sunlight or to the ultra-violet rays converts foods that allow the development of rickets to foods that cure and prevent rickets and do other things which sunlight or ultra-violet rays are capable of. All foods contain ergosterol or a compound simi-

lar to it. This substance has the power to absorb ultra-violet and to hold it for future biologic use. Several food companies have already caught the possibilities of adding nutritional value to their products and have already put on the market irradiated foods.

A very striking and interesting effect of sunlight or of ultra-violet and even of substances like cod-liver oil that contain vitamin D is its ability to increase the acidity of the stomach. The stomach under normal conditions has a certain amount of hydrochloric acid. This amount of acid serves to destroy bacteria which enter the stomach by way of the mouth and by way of the large intestine. Without this acid or with too little acid in the stomach and intestines, bacteria find their way into these organs, penetrate the walls, circulate in the blood and start an infection somewhere in the body. When a person is unable to disinfect himself on account of insufficient acid in the stomach he is in danger of harboring infection.

The acid of the stomach washes down into the upper part of the small intestine and keeps that part of the alimentary tract in an acid condition. Intestinal acidity is very essential to the health of a person. When the upper part of the intestine is neutral or alkaline, not only does it become highly bacterialized, but the calcium, phosphorus and iron of the food fail to be absorbed and pass out of the body unused.

As a result of inability to use calcium and phosphorus, a child develops rickets or infantile tetany. As a result of inability to use iron a young person or an adult is sure to develop anemia. Anemia in the child or in the adult is more common in winter than in summer. The symptoms of anemia are also severer in winter than in summer.

The value of ultra-violet in the treatment of anemia has again been recently demonstrated at the Iowa State College. Dr. Jongewaard observed that two thirds of the girls coming to the clinic had secondary anemia, the hemoglobin ranging from 50 to 70 per cent. He advised these girls to take a diet rich in hemoglobin-building material, to go to bed early and to stay out of doors as much as possible. He also treated them with ultra-violet rays. His findings have led him to the conclusion that sunshine is a part of nature's mechanism for promoting the assimilation of iron and for the production of hemoglobin and red cells.

Sunlight serves as a mental and emotional stimulant. It has a tonic effect on the mind. Mental tests for children in England attending sun classes bring out the fact that as a result of mere exposure to sunlight the pupils showed marked improvement in mental capacity and in general alertness arising from rapid coordination of thought and action. Sir Henry Gauvain in his work at the Lord Mayor Treolar Cripple's Hospital and College at Alton, England, noted that the London school children and the crippled lads who did not take sun baths averaged one year in mentality behind the tuberculous children who were treated by light.

At the commencement of the sun classes in the English observations, many of the pupils were listless, tired or lazy. As the sun classes continued, they gained in self-confidence, in self-reliance and in powers of observation. They finally developed excellent *esprit de corps,* increased vitality and initiative. Aimlessness and lassitude disappeared and the children manifested a constant craving to tackle a set piece of work and to get it completed.

Sunlight or ultra-violet light also favorably influences the emotions. It exhilarates and induces a sense of gaiety and well-being. It dissipates gloom and depression. Few people commit suicide on days of sunshine. Most of the suicides occur on drab days and during the

sunless winter months. In this connection it is apropos to cite Norman Davey:

> The sun is a dispeller of ill-humor. He is the healer, the life-giver. He is the only true doctor of the troubled mind. He is the best apothecary in the world. There is no tonic sold for gold over any druggist's counter so remedial as that celestial pick-me-up which is poured for nothing each morning over that wide counter which is the brim of the earth.

On the walls of Dr. Rollier's consulting room in his famous light sanatorium the famous inscription is to be read: *De toutes les fleurs la coeur humaine est ce qui a le plus besoin de soleil.*

Keyserling in the "Travel Diary of a Philosopher" exclaims,

> What would man be without sun? He would not exist at all. The whole of his being is sun-produced, sun-born, supported by the sun and withers when the mainspring of life turns away. The more I advance in recognition the more I profess sun-worship myself. During these terrible months when the sun only throws a hasty, disdainful greeting upon Esthonia . . . the curve of my life declines every time. My body feels ill, my vitality decreases, my soul loses in tension. And conversely, periods of my highest creative power always coincide with the longest days.

Youth must live in the light. It is therefore no wonder that great artists have endeavored to depict on the same canvas the spirit of youth and sunshine. Vincent Homer, George Bellows and Frank Benson have awakened through their paintings the longing for the spontaneous enjoyment of outdoor life, of fresh breezes and bright sunny days. Sorolla y Bastida, of Spain, is another painter of sunshine. His magnificent paintings are flooded with it and vibrate with the jollity of youth.

To be out in the open air whenever possible and as long as possible is the great need for every man, woman and child. Too much time altogether is spent indoors. The sun bath is even more essential as a means of conserving health than the water bath. The hundreds of thousands of persons who visit the seashore for the purpose of sea bathing derive great benefit from exercise in the sea water, but much greater benefit from the exposure of their bodies to the sun.

Too many people fail to get the bliss that comes from sprawling on the green turf and playing and working close to Mother Earth. Too many people are ill from sunshine starvation. The individual who thinks that he is out in the open in his closed automobile fails to realize that it is his car and not he that is getting a sun-bath and the beneficent ultra-violet rays. To the great number of invalids who are bedridden we have to add another and surprisingly larger group of individuals who are auto-ridden.

No wonder that Richet called man "homo stultissimus," or "idiot-man," because, having knowledge of the prevention of disease, he does not apply that knowledge to the best of his advantage.

A CAPTIVE-BORN CHIMPANZEE

By BESSIE A. WHITE

SECRETARY, LABORATORY OF COMPARATIVE PATHOLOGY, PHILADELPHIA ZOOLOGICAL SOCIETY

"THERE he is, and I wish you luck!" With these cheering words did a tired and nerve-wracked keeper place in my outstretched hands 1,720 grams of cold, starved, cage-dirty anthropoidism, just forty-eight hours old, and with forty-nine centimeters of atrophied umbilical cord still attached. Two days before, on October 1, 1928, our fine, big chimpanzee, Marianne, had given birth to this baby, and although she seemed to be a very tender and adoring mother and very solicitous of her offspring in all other ways, she made no attempt to nurse it or even to take it up in her arms. She herself missed not one feeding, even the day it was born. She sat by it, crouched in a protecting attitude, and when she did move away, the faintest whimper brought her hurrying back to nuzzle it and respond to its cries with a soft, purring note. For two days she was left undisturbed, in the hope that the nursing instinct would develop sufficiently to prompt her to take the little one up against her breast; but as the little body grew steadily colder and the cries weaker, it was decided to take him from her and try artificial rearing. The little mite was apparently oblivious to his surroundings, but even as I softened with vaseline the dried accumulations of meconium, and prepared to wrap him in wool flannel, he clutched my apron with a strong grip, which little act promptly transformed him, in my mind at least, from a newborn chimpanzee to a forlorn little baby, desperately in need of a mother. A full scientific description of his size and general appearance at this time will be found in an article by Dr. Herbert Fox, "The Birth of Two Anthropoid Apes," *Journal of Mammalogy*, February, 1929.

After one and one half hours exposure to a warm October sun, a rectal thermometer was inserted. It did not register. External heat was applied in the form of hot water bottles, and the little body was held in a warm oven several times for two or three-minute intervals. Later an electric stove was placed so the heat was reflected directly upon him. At 4:00 P. M., the thermometer was again inserted, with the same result. The external heat was continued, however, and by 5:30 P. M., he was perceptibly warmer. His temperature at this time was 97.6° F.

He voided urine frequently, but had no further stool after being taken from the mother until he was given a half teaspoonful of milk of magnesia on his fifth day. This brought a large, dark brown stool, showing traces of meconium. From then on, all stools were of a bright yellow, soft-formed, and averaging three of about two ounces each in twenty-four hours.

Feeding for the first forty-eight hours after he was received at the laboratory was by means of a medicine dropper, swallowing being induced by tipping the head back or massaging the throat, sometimes both. Some of the first few feedings were regurgitated, but by evening he was retaining all of it. On the advice of Dr. J. C. Gittings, he was given evaporated milk diluted with six parts of water, one half ounce being all he could be induced to take at a time. This was given every two hours, day and night. Early on the third day of this artificial feeding, he suddenly began searching excitedly with his mouth. Lest he lose the inspiration, an empty nipple was quickly thrust between his parted lips. He sucked vigorously for a

minute while a hastily prepared bottle was being attached to the nipple. His medicine dropper feedings were over. The attention he gave that bottle would please the most anxious mother. At the age of one week, he was taking from ten to twelve ounces of diluted milk in twenty-four hours.

During the first three weeks, he lost weight, dropping from 1,720 grams to 1,440 grams. On the twentieth day, one half teaspoonful of cane sugar was added to the daily quantity of milk formula, and at the age of four weeks, he weighed 1,574 grams; at the end of the second month, 2,136 grams; third month 2,514 grams; fourth month 2,923 grams; fifth month 3,220 grams; sixth month 3,544 grams. Experience showed that the sugar, while it seemed to promote a gain in weight, could be increased only very gradually, and at the first sign of diarrhea was cut entirely until the stools were again normal. At the age of six months, one and one half teaspoonfuls to the daily quantity of formula, twenty ounces, seemed the proper amount.

Early in January, raw, unpasteurized milk, diluted to correspond with the evaporated milk formula, was substituted for one feeding a day. As no unfavorable results followed a few days of this, the raw milk was used exclusively thereafter, with the exception of a few days when it was deemed wiser to boil the milk because of a slight diarrhea.

At the age of four and one half months, a tablespoonful of oatmeal gruel was added to one feeding a day, and two weeks later, the yolk of an egg was added to the day's formula twice a week. Vegetable purees were then tried, first spinach and, later, pea, but these were effectively scorned. Nor did these latter foods meet with any greater favor with our older chimpanzee "Lizzie" and the gorilla.

Considering the six months as a whole, there was really very little trouble with the digestive tract, and, as we learned later, the development of bone and muscle was progressing very satisfactorily. During October, his first month, and occasionally during November, it was possible to give him the benefit of direct sunshine for short periods, but with the exception of a few mild days in February, it was necessary to suspend this during the winter months. In the absence of definite records of teething in the chimpanzee, at least it can be said that this was proceeding normally, although perhaps a bit retarded, due to lack of natural feeding.

During the fifth month, when he was making definite attempts to draw the bottle to his mouth unaided, care was taken that both hands were left free. Almost every time he used the left hand, even though he did not attempt to clutch anything with the right at the same time. The question rises—was the right, from instinct, left free for emergencies, such as falling or sudden need to move? Very early, it was learned that he could take his bottle much more comfortably if held in an upright position. At such times he kept a firm grip on the clothing of nurse or keeper, but as he grew older this clutching instinct gradually diminished, as though he no longer feared falling.

During the latter part of the first month, orange juice and cod-liver oil were added to his diet in small amounts. This resulted in intestinal disturbances, as did subsequent attempts. During the third month, however, the results were more favorable, and by the end of the third month, he was taking one half teaspoonful of orange juice and ten drops of cod-liver oil daily.

Early in December he was drooling at the mouth after the manner of teething babies. His first tooth, the right lower incisor, appeared January 29, when he was almost four months old. The left was through February 16. Nearly a month later, March 13, the right upper incisor was plainly felt, fol-

lowed ten days later by the left. Three days later, the lower left lateral incisor appeared, and the right was all but through at the time of his death on April 12. During this teething period he seemed anxious to bite on any firm substance within reach, but at no time was there any marked swelling or other sign of undue inflammation.

During the early weeks, although his eyes were wide open and bright, he was apparently incapable of focusing his vision. His hearing and sensitiveness to touch, however, seemed very acute. At the slightest sound or the most careful adjustment of his covers, he would start violently. At the end of the first month, his eyes seemed to have more expression and he appeared to be beginning to correlate sight and sound. If a person stood at the foot of his basket and talked to him, his eyes would be directed at that person. If the person moved away, but ceased talking, his eyes would remain directed as before; but if the person resumed speaking after moving, the baby's eyes would almost invariably follow the sound. At the age of six weeks there seemed to be no doubt that he could focus his vision.

By the time he was two months old, he would frequently give a short responsive bark or grunt when spoken to, and sometimes tried to imitate the "ooh-ooh-ooh" of his elders. He seemed to enjoy attention just as a human baby does, and favored us with his first smile at the age of six weeks. Whether he preferred men to women it is impossible to state, but certainly he responded more readily to a man's voice than to a woman's.

By this time he had developed a vigorous temper, and did not hesitate to display it if his bottle was too long delayed to suit him. He would start with a series of grunts, which would soon reach a high-pitched "ooh-ooh-ooh," and then a succession of shrill screams so intense that they usually choked him into a few seconds of breathless silence. As soon as he recovered his breath, the same tactics were resumed until the desired bottle was forthcoming. At this age he seemed to recognize the keeper and me, regardless of whether we were in our working uniforms or in street clothes.

He certainly seemed to have two types of response when spoken to. To Mr. McCrossen and myself, and a few others, he returned a soft, sometimes throaty, "ooh-ooh-ooh," but to certain others he replied with a sharp, excited bark, which must have been indicative of dislike, because later when one of these men had part of the care of him, he gradually tempered his response to him from the shill bark to the friendly greeting that he reserved for those who had the more intimate care of him.

Nor were his discriminatory powers limited to persons. He very early learned to associate a spoon with cod-liver oil, and fought vigorously against taking anything by that method, unless "primed" by a taste from a finger dipped in the food.

During the first few weeks, he would lie in his basket in the position in which he was placed, but soon showed a decided preference for lying on his back. He liked to be held, his favorite position being upright against a person's shoulder. During the fifth and sixth month, he remained awake much more during the day, and then would frequently turn from his back to his side and back again in his play, often pulling on a bar or other object to help himself over. Bits of rope, some with teething rings or other toys tied to them, were suspended within convenient reach, and these also were frequently used to help himself about. A popular position was to turn on his side and raise his head and shoulders, supporting himself on his forearm.

In the matter of activity and development of locomotive powers, this baby probably missed his mother fully as

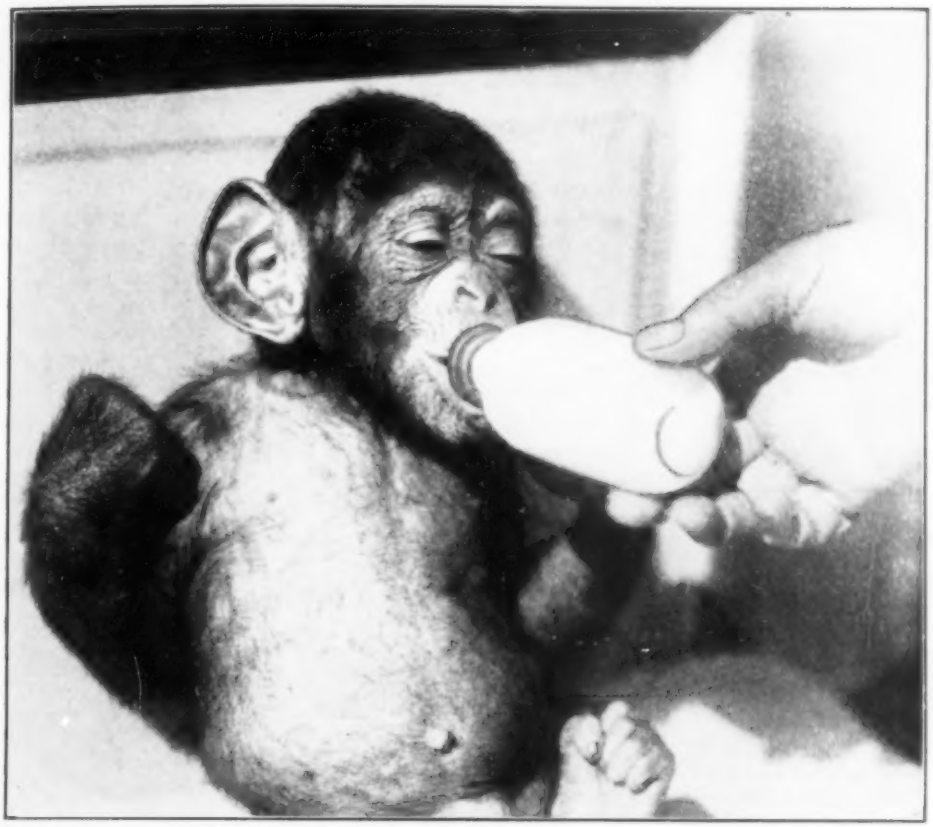
THE CHIMPANZEE, "JULIUS," AT THE AGE OF SIX WEEKS

THIS SHOWS WELL THE SKIN FOLDS AND FACIAL FORMATION. THE VERY LONG HAIR IN THE FRONTAL REGION WAS SHED OUT IN A FEW MONTHS AS INDICATED BY THE OTHER PHOTOGRAPH.

much, if not more than in the matter of nourishment. The baby orang-utan, "Lucky," only six days older than this baby chimpanzee, "Julius," was able at the age of three months to cling to the bars with all four limbs, and get about by himself as far as his solicitous mother would permit. "Julius," on the other hand, missed the rough-and-tumble handling that was the lot of the little orang-utan from his second day in the world, when the mother orang calmly draped him across her hip and left him to cling for himself while she moved about the cage. This enforced use of his muscles certainly must have gone far toward developing them. Nor does he seem to resent this schooling in self-reliance. If he crawls too far away to please "Maggie," his mother, she reaches out with either arm or leg, grasps him by the most convenient part and retrieves him. I have seen her cup her two feet about his little head and pull him. At such times he evidently thinks co-operation is the wisest policy, because he usually grasps her hair, thus relieving the traction on himself. All this gymnastic play little "Julius" missed, because monkey-house keepers and laboratory assistants, as a rule, do not have as much spare time as does a captive orang.

Scratching—characteristic of all animals, but perhaps more closely associated with the primates—was first noticed in this chimpanzee at the age of three and one half months, feeble but unmistakable. It would seem that this must have been an impulse of the fingers rather than the consciousness of any need of it, because he would perform the same service on the arm or face of a person holding him and with equal attention to technique. During the first six weeks, he would all too frequently scratch his face in an alarmingly vigorous, but altogether different manner. The outspread palm would, either by intention or accident, come in contact with his face, and immediately the flexed fingers would be drawn down the face as though to pull away something that might be annoying him or obstructing his vision. This resulted in many little abrasions, one of which, at the left side of the base of the nose, after many disturbances of the scab, developed into one of the dark pigmented spots so common on the faces of these animals. There may be some significance to the fact that after the power of focusing his vision seemed definitely established, this little mannerism of face scratching ceased.

No human baby ever enjoyed the exquisite flavor of his toes any more than did this tiny ape. As soon as the early morning bottle was finished and he was returned to his bed, he always managed to capture one foot, and holding it to his mouth with both hands, would bite and suck on it to his heart's content. During the process of restoring the laboratory work-room from an improvised nursery to its normal appearance, it was difficult to pass his box without pausing for a word. Immediately the foot was withdrawn from his mouth and I was greeted with a face-wide smile, usually the foot being generously offered to me for a taste. However, when I appeared at his side with my coat on, the signal that he was about to be taken back to the monkey house for the day, all play was promptly abandoned and he immediately became very tense. If I didn't take him up at once, he would hold up both arms, purse his lips and begin a soft "ooh-ooh-ooh," a perfect picture of anxious pleading. Whether the presence of the coat had any effect on him or not, it is impossible to state. The interval between the first bottle and his removal to the monkey house was about the same each day. Perhaps it was coincidence that he was tired of lying in his box after that length of time, and wanted to be taken up. Again, perhaps he had learned to look for that little inci-



THE CHIMPANZEE "JULIUS," AT THE AGE OF FOUR AND ONE HALF MONTHS
THIS WAS THE EXPRESSION WHEN THE ANIMAL WAS PLACID. IT SHOWS VERY WELL THE FORM OF FIST-MAKING

dent in his daily routine just as he looked for his feeding. On the other hand, no matter how many times I stopped at his box, he seemed contented to lie there and play until I appeared with the coat on. When the return trip from the monkey house to the laboratory was made in the evening, he was usually asleep, and roused only partially as he was taken up.

This fascinating picture of babyhood, differing from the human only anatomically, was progressing serenely until the end of the sixth month, when clouds appeared on the horizon. A restless night —fever—two weeks of illness and suspense—and on April 12, the soul of the only captive-born, bottle-fed chimpanzee on record swung back to the celestial jungles, leaving the little body to pathology, zoology and all the various other "ologies" so dear to science.

The first question that rises in the mind of the reader—and naturally—is, why was the bottle feeding necessary? Why did not the mother ape suckle this baby? Many theories have been advanced, but none can be proven the correct one. The smaller, old world monkeys are known to eat the placenta shortly after it is expelled. This mother, "Marianne," did not eat the placenta at this birth, nor did she offer any objection when it was removed from the cage nearly two hours later, although

she had very evidently mouthed it, perhaps sucked blood from it, as shown by blood on her face after having her head down in the straw where it had fallen, and also by tears in the afterbirth. Neither did "Maggie," the orang-utan mother, make any attempt to eat hers, but simply severed the cord with her teeth after approximately twenty-eight hours and pushed the placenta over against the door of her cage, as she might do with anything she didn't want. Lactation in "Maggie" has apparently been entirely normal, and she has been a model mother. Dr. H. H. Donaldson, when consulted in the matter, expresed the opinion that perhaps the presence of visitors and members of the Garden personnel may have disturbed "Marianne" by depriving her of the privacy she might be expected to seek. However, both the inner and outer cages have dens to which she could easily have retired had she so desired; but when it was known beyond doubt that she was in labor, she still remained in the most exposed part of her quarters. Dr. Donaldson suggested further that the separation of the male and female at almost the height of labor might have frightened her and made her unduly apprehensive. It is highly probable that "Marianne's" neglect was due to a combination of causes and it is the opinion of the writer that her youth was no small factor.

That she was not entirely lacking in maternal instinct is shown by the fact that she cuddled and mouthed the baby, showed deep concern and solicitude when he cried, and resented his being taken from her. Mr. J. L. Buck, who brought her from Africa when she was approximately three years old, tells how at that time she "mothered" a smaller chimpanzee in the same group, cuddling him to her breast and struggling valiantly to carry him about, even though he was not a great deal smaller than herself, and well able to walk. Her own offspring she made no attempt to pick up.

In like manner "Josephine," another chimpanzee, presented to the Zoological Gardens by Mr. Alfred M. Collins, "mothered" little two-year-old "Napoleon" when he was allowed in her cage. At first, the little fellow's visits were necessarily limited, lest he become too tired from the unaccustomed excitement and play. "Josephine" soon learned that attempts to entice one or the other of them into another compartment of the cage were for the sole purpose of separating them, and she was always on the alert to prevent this. I have seen her take up a position beside him so that he was near her hip, give a low bark and wait; but "Napoleon" continued with his play. She turned, gave him a sharp slap on the back of the head and resumed her position of waiting. "Napoleon" was evidently satisfied where he was, but thoroughly understood what was expected of him. He beat the floor with his hands and screamed a few times to register his protest, but nevertheless scrambled hastily to her back and was borne away to the outside cage.

For some time before "Josephine" came to the Garden, she had had a Schmidt's monkey as a cage mate. This little creature also served as an outlet for "Josephine's" maternal instinct. She carried him about, clinging to her breast, wherever she went. One night they were placed in separate cages, but morning found both cages broken open, and "Josephine" cuddling her adopted baby as usual. "Josephine" was unquestionably a nullipara, having been brought from Africa before she was fully adult; but the maternal instinct was surely a large part of her emotional make-up. Unfortunately it was not possible to give her an opportunity to breed in the three and one half years she lived at the Zoo.

However, the instinct to cuddle and protect the young seems not confined to the females. The above-mentioned "Napoleon," now about four years old, when allowed to approach this baby of his own kind, immediately tried to take it up. When he found this was not allowed, he put both arms around it and patted it gently. When the baby cried, he tightened his embrace and speeded up the patting. The baby grasped the hair on his arm, and although "Napoleon's" attention was soon attracted elsewhere, he held the captive arm perfectly still and made no attempt to free it from the baby fingers. On the other hand, as one baby to another, these apes seem all too human. Little "Orphan Annie," the year-old orang-utan, was not so gentle, and while she would touch him very gently at first, she would slyly watch for a chance to pull his arm or leg; but her chief delight was to steal his covers with which she immediately proceeded to adorn herself. The baby himself watched these other animals very solemnly and made no attempt to play with them.

When this baby chimpanzee was shown to his mother for the first time after removing him from her cage (about two months later), she came forward to the bars, gave a few short barks and gazed intently at him. The same thing happened on two or three subsequent occasions, but after that "Marianne" simply gave him a bored look and continued what she had been doing.

Despite his mother's indifference, this little ape seemed to thrive very well under artificial feeding, because after death it was discovered that bony and muscular development was all that could be expected in a normal breast-fed animal. We take this as an indication that our attempts to approximate his normal alimentary needs were successful. His death was due to an acute infection that not infrequently attacks even the most carefully guarded, breast-fed human babies. A detailed account by Dr. Fox of this final illness and the findings at autopsy will appear in the Zoological Society's laboratory report for 1930.

—*Bachrach*

A RECENT PHOTOGRAPH OF MR. EDISON

THE PROGRESS OF SCIENCE

IN HONOR OF MR. EDISON[1]

THIS ceremony is a part of the celebration of Mr. Edison's invention of the electric lamp. It is also the dedication of the Edison Institute of Technology, the gift of Mr. Ford. Both are in fact national tributes to Mr. Edison.

The multiplication of the amount of light in the world a thousandfold is worthy of celebration, for darkness is a forbidding limitation upon righteous human activities.

When Mr. Edison invented the electric lamp he may perhaps have thought just to produce plain light and more of it at less cost. I surmise that his wildest ambition was to relieve the human race from the curse of always cleaning oil lamps, scrubbing up candle drips and everlastingly carrying one or the other of them about. He may have thought to add safety to Chicago against a second accident from an oil lamp.

But the electric lamp has found infinite variety of unexpected uses. It enables us to postpone our spectacles for a few years longer; it has made reading in bed infinitely more comfortable; by merely pushing a button we have introduced the element of surprise in dealing with burglars; the goblins that lived in dark corners and under the bed have now been driven to the outdoors; evil deeds which inhabit the dark have been driven back into the farthest retreats of the night; it enables the doctor to peer into the recesses of our insides; it substitutes for the hot-water bottle in aches and pains; it enables our cities and towns to clothe themselves in gaiety by night, no matter how sad their appearance may be by day.

And by all its multiple uses it has lengthened the hours of our active lives, decreased our fears, replaced the dark with good cheer, increased our safety, decreased our toil and enabled us to read the type in the telephone book. It has become the friend of man and child.

In making this, as in his other great inventions, Mr. Edison gave an outstanding illustration of the value of the modern method and system of invention, by which highly equipped, definitely organized laboratory research transforms the raw material of scientific knowledge into new tools for the hand of man.

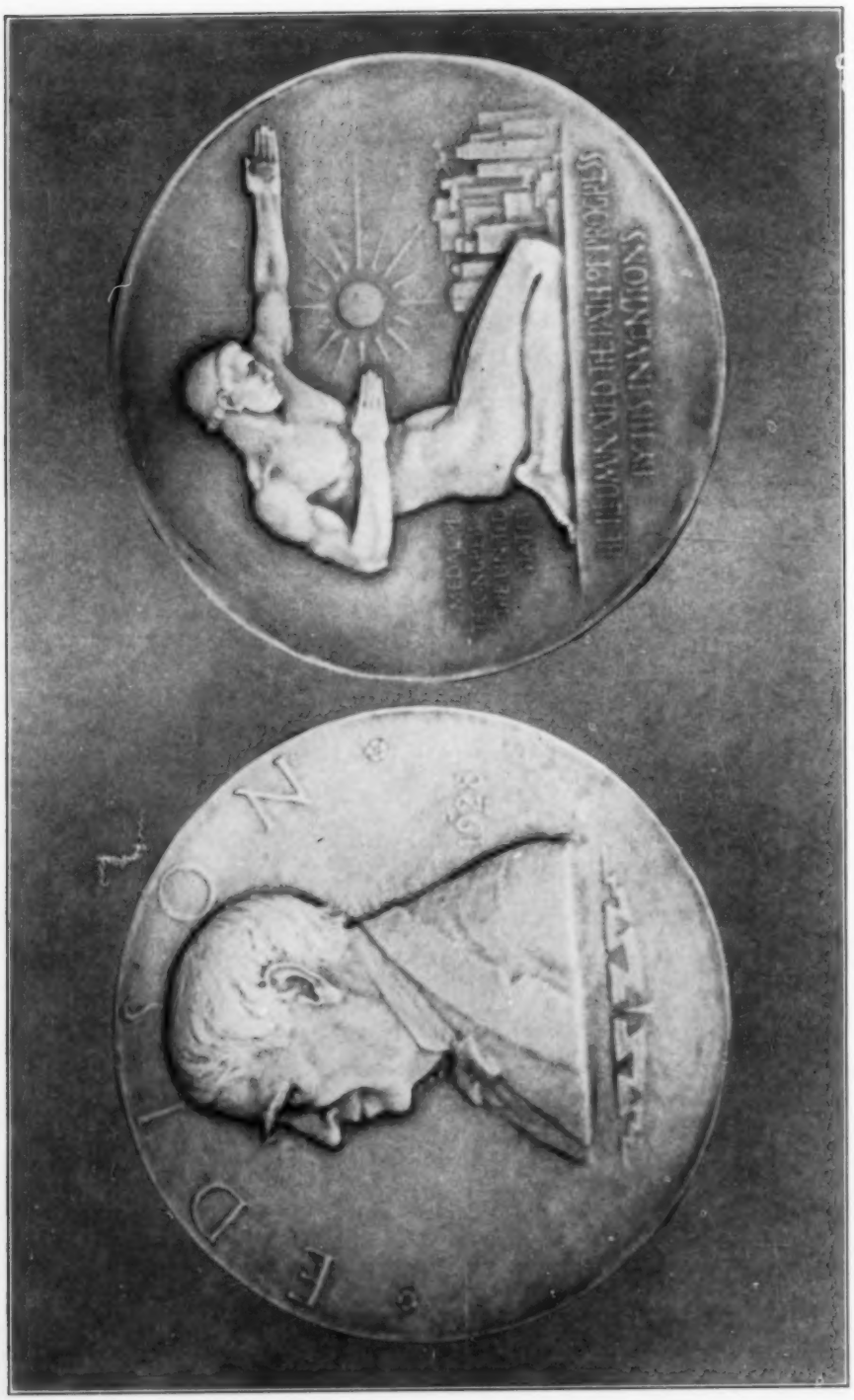
In the earlier times, mechanical invention had been the infrequent and haphazard product of genius in the woodshed. But science has become too sophisticated a being to be wooed in such surroundings. Nowadays a thousand applied science laboratories, supported by industries of our country, yearly produce a host of new inventions.

I can perhaps illustrate this modern method of invention. The fundamental natural laws of electricity were discovered three quarters of a century ago by Faraday, Hertz, Maxwell and other great investigators in the realms of pure physics and mathematics. Faraday discovered that energy could be transformed into electricity through induction — the theory of the electrical generator. It was one of the momentous discoveries of history.

It is related that Mr. Gladstone was induced to visit Faraday's laboratory to see this new scientific contraption. When Gladstone is said to have made the characteristic practical man's inquiry, "Will this ever be of use to mankind?" Faraday replied, "Some day you will collect taxes from it."

Mr. Edison, using organized systematic laboratory research, has been one of the great leaders who have converted the pure physics of electricity into a taxable

[1] Address given by President Hoover at Dearborn, Michigan, on October 21.



CONGRESSIONAL MEDAL STRUCK IN HONOR OF THOMAS ALVA EDISON

—*Associated Press*

product. To-day the governments of the world levy upon upward of $60,000,000,000 of new wealth founded upon electricity.

But the taxes and new wealth are not the major accomplishments of the men of this genus. These are the rivers of sweat saved from the backs of men and the infinite drudgery relieved from the hands of women.

I may emphasize that both scientific discovery and its practical application are the products of long and arduous research. Discovery and invention do not spring full-grown from the brains of men. The labor of a host of men, great laboratories, long, patient, scientific experiment build up the structure of knowledge, not stone by stone, but particle by particle. This adding of fact to fact some day brings forth a revolutionary discovery, an illuminating hypothesis, a great generalization or a practical invention.

Research both in pure science and in its application to the arts is one of the most potent impulses to progress. For it is organized research that gives daily improvement in machines and processes, in methods of agriculture, in the protection of health and in understanding. From these we gain constantly in better standards of living, more stability of employment, lessened toil, lengthened human life and decreased suffering. In the end our leisure expands, our interest in life enlarges, our vision stretches. There is more joy in life.

It is the increasing productivity of men's labor through the tools given us by science that shattered the gloomy prophecies of Malthus.

More than a century ago that great student held that increasing population would outrun the food supply and starvation was to be the inevitable executioner of the overcrowded earth.

But since his day we have seen the paradox of the growth of population far beyond anything of which he ever dreamed, coupled at the same time with constantly increasing standards of living and ever-increasing surplus of food. Malthus was right except for a new contestant in the race with his principle: That was more scientific research, more discovery. And that race is still on. If we would have our country improve its standards of living and at the same time accommodate itself to increasing population we must maintain on an even more liberal scale than ever before our great laboratories of both pure and applied science.

Our scientists and inventors are amongst our most priceless national possessions. There is no sum that the world could not afford to pay these men who have that originality of mind, that devotion and industry to carry scientific thought forward in steps and strides until it spreads to the comfort of every home, not by all the profits of all the banks in the world can we measure the contribution which these men make to our progress.

And they are the least interested in the monetary results. Their satisfactions are in their accomplishment—in the contribution of some atom of knowledge which will become part of the great mechanism of progress. Their discoveries are not the material for headlines. Their names are usually known but to a few. But the nation owes them a great honor and is proud to demonstrate through Mr. Edison to-day that their efforts are not unappreciated.

The country can well pay its tribute to the men of this genus by expanding the facilities for their labors. The nation to-day needs more support for research. It needs still more laboratories. To that Mr. Ford is making a generous contribution.

And in establishing this institute, Mr. Ford is doing honor to Mr. Edison in a manner which appeals to a sense of fitness—that is, by founding an institution

MME. CURIE AND PRESIDENT HOOVER

A PHOTOGRAPH TAKEN AT THE BUILDING OF THE NATIONAL ACADEMY OF SCIENCES WHERE PRESIDENT HOOVER PRESENTED MME. CURIE WITH A FUND FOR THE PURCHASE OF RADIUM

dedicated to education and scientific research.

And scientific research means more than its practical results in increased living comfort. The future of our nation is not merely a question of the development of our industries, of reducing the cost of living, of multiplying our harvests or of larger leisure. We must constantly strengthen the fiber of national life by the inculcation of that veracity of thought which springs from the search for truth. From its pursuit we shall discover the unfolding of beauty, we shall stimulate the aspiration for knowledge, we shall ever widen human understanding.

Mr. Edison has given a long life to such service. Every American owes a debt to him. It is not alone a debt for great benefactions he has brought to mankind, but also a debt for the honor he has brought to our country. Mr. Edison by his own genius and effort rose from modest beginnings to membership among the leaders of men. His life gives renewed confidence that our institutions hold open the door of opportunity to all those who would enter.

Our civilization is much like a garden. It is to be appraised by the quality of its blooms. In degree as we fertilize its soil with liberty, as we maintain diligence in cultivation and guardianship against destructive forces, do we then produce those blossoms, the fragrance of whose lives stimulates renewed endeavor, gives to us the courage to renewed effort and confidence of the future.

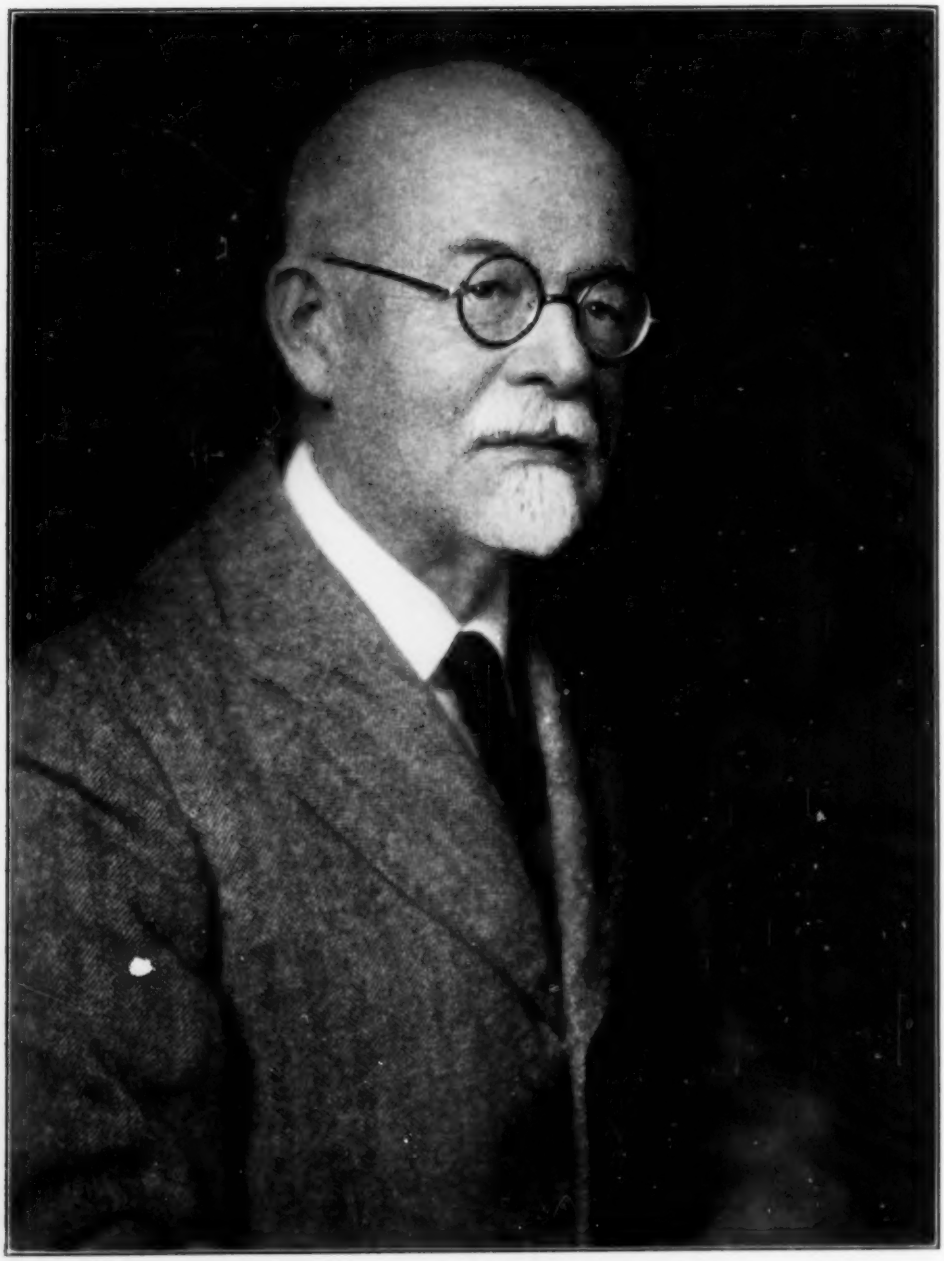
THE AWARD OF THE FREDERIC IVES MEDAL TO PROFESSOR NICHOLS

THE Optical Society of America at its recent meeting at Cornell University, October 24 to 26, awarded the Frederic Ives medal to Professor Edward L. Nichols, professor emeritus of physics at Cornell University. This medal was endowed in 1928 by Dr. Herbert E. Ives, in honor of his father, Mr. Frederic Ives, distinguished for his pioneer contributions to color photography, photogravure, three-color process printing and other branches of applied optics. It is awarded biennially for distinguished work in optics. Professor Nichols, one of the five honorary members of the Optical Society, is the first recipient of the medal. The presentation took place at a dinner arranged jointly by the Optical Society of America and the colleagues of Professor Nichols on the faculty of Cornell University.

Professor Nichols' contributions to science and his activities in connection with American scientific societies are so well known as to require only passing comment. After receiving the B. S. degree at Cornell in 1875, he studied successively in Leipzig, Berlin and Göttingen, from which latter university he received the doctorate in 1879. He was a fellow at Hopkins in 1879–80, and for a short time thereafter was associated with Edison in the development of the incandescent lamp, particularly with reference to photometric methods of measurements of candle-power.

After serving as professor of physics successively at the University of Kentucky and at the University of Kansas, Professor Nichols was called to his alma mater as professor of physics in 1887, which post he still holds, becoming professor emeritus in 1919.

During the period of thirty-two years from 1887 to 1919 while he was director of the department of physics at Cornell University, there passed through the department a large number of graduate students and instructors who now hold positions of responsibility throughout the entire country. A large number of these returned to Cornell to attend the



PROFESSOR EDWARD LEAMINGTON NICHOLS

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THE · OPTICAL · SOCIETY
OF · AMERICA
TO
EDWARD LEAMINGTON NICHOLS

THE FREDERIC IVES MEDAL AWARDED TO PROFESSOR NICHOLS

physics conference and reunion upon the occasion of Professor Nichols' retirement as director in 1919.

Professor Nichols is a member of many scientific societies, including the National Academy of Sciences; the American Association for the Advancement of Science, of which he was president in 1907; the American Physical Society, of which he was president in 1907–09; Sigma Xi, of which he was national president in 1908. He was active in founding the American Physical Society and was instrumental in starting the *Physical Review*, the outstanding journal of physics in America.

His first paper was published in 1879. In the intervening fifty years there has been scarcely a year during which he has not published several papers, as the results of his own investigations and with various collaborators, in the fields of photometry, spectrophotometry and luminescence, to which latter subject he has devoted a very large proportion of his attention during the past twenty-five years. Although he became professor emeritus ten years ago, he is still as busy as ever with his collaborators in the physics laboratory at Cornell University extending his investigations in this important field.

With the assistance of Professor H. L. Howes and Mr. D. T. Wilber, Professor Nichols published in 1928 a 350-page report of his work on cathodoluminescence and the luminescence of incandescent solids, a field in which he has been at work for a number of years. This report is remarkable in several ways. It presents a vast amount of information on this very complex subject on the basis of which, in due course, theories will doubtless be built. Of more significance, however, is the fact that a large part of this work has been either done by Professor Nichols personally or directed by him since his retirement from active service ten years ago. Indeed, it is one of the great sources of inspiration to those of us who have had the great good fortune to be colleagues of Professor Nichols in the physics laboratory at Cornell University to see him maintain, even with increased vigor, his activities in research subsequent to his retirement. Many regard the accomplishments of these last ten years as representing the best work of his long and distinguished career.

However much Professor Nichols is esteemed as a scientist by those who have worked with and under him or have watched his accomplishments from the

outside, still more striking are his personal qualities as seen by those who have had the rare privilege of knowing him as a man. His elementary lectures to undergraduates were always fascinating but many a student has stated that he carried away from the lecture room something far more valuable than the information so clearly imparted by this skilled teacher over the lecture table. There was about his lectures a quiet dignity, an unaffected simplicity, a respect for and a love of all knowledge, which could not but be infectious. Graduate students and the younger members of his staff have profited still more from these rare qualities of his by virtue of their closer contacts with him.

A single instance out of my own personal experience will suffice to indicate the basis of the love and esteem with which Professor Nichols is regarded. When I came to Cornell as an untutored freshman I had a hazy notion that I wished to study electricity, and I made my way to the physics building for advice. Upon entering the hall, the first person whom I saw was the man who, as I learned later, was head of the department, Professor Nichols. I asked if I could find some one who could give me advice with regard to the courses of study which I should take in order to become acquainted with the field of electricity. Instead of referring me to some one else, he immediately, in the most kindly and unreserved yet dignified manner, asked me further about my plans and desires. His attitude was so sympathetic and so full of cordiality, yet without the slightest suggestion of condescension, that I was at once possessed of a desire so to shape my undergraduate course as to come more directly into contact with this man. In a very few moments he outlined to me a course of study which I should follow—and which indeed I did follow almost without change. Further, he gave me, a student quite unknown to him, a cordial invitation to come to him at any time in connection with my course of study. Had I never met Professor Nichols again, those few moments would have stood out in my memory as among the most inspiring of a lifetime. But subsequent contacts in the department later as a graduate student, instructor and member of the staff have been even fuller of inspiration and encouragement.

Every one who has worked with or under Professor Nichols can relate similar instances—all of which serve to explain the veneration in which this great scientist and teacher is held by those who have been associated with him.

F. K. RICHTMYER

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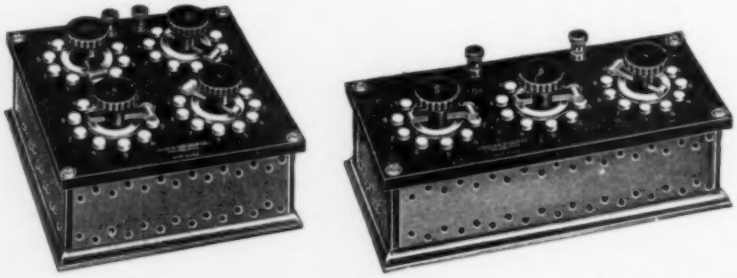

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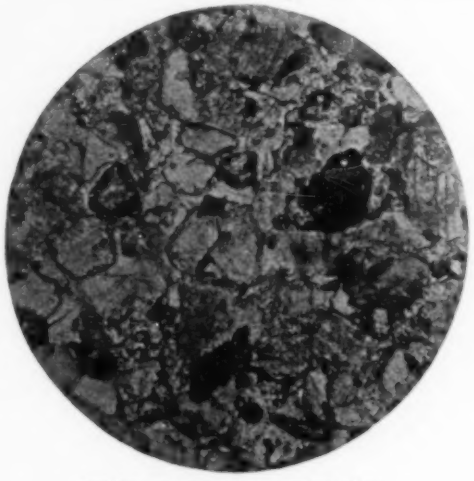

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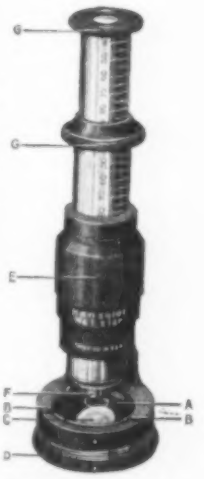

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